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MATERNAL BEHAVIOR AND BEHAVIORAL DEVELOPMENT IN TWO SUBSPECIES OF *PEROMYSCUS MANICULATUS*

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This study represents an initial step into the problem of the phylogeny of behavior in *Peromyscus*. The aim of the entire study is to examine the patterns of behavior in this genus and to ascertain their relation to the ecological adaptations of each species and subspecies studied. The demonstration of subspecific similarities and differences must first be undertaken, and the present paper is concerned with this aspect in the subspecies *Peromyscus maniculatus bairdi* and *P. m. gracilis*. These two subspecies are of particular interest because they represent the end products of a Rassenkreis whose ranges have recently overlapped (Hooper, 1942). Other studies of these subspecies in the field (Blair, 1940, 1942; Howard, 1949; Manville, 1949) and in the laboratory (Harris, 1952, 1954) render them useful for a comparative study.

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METHODS

Animals.—The mice used in this study were derived from stocks captured in Michigan and bred in the laboratory since 1947–48 (Harris, 1952). The mice were originally kept at the Laboratory of Vertebrate Biology at the University of Michigan and were sent to me by Drs. W. Prychodko and W. McIntosh. The stocks had been raised in the R. B. Jackson Memorial Laboratory for at least a year before the mice were selected for study.

Treatment.—The mothers in this study were weaned at 30 days of age and kept in isolation until the tests began from 6 to 8 months of age. They were first given two tests for aggression, a hoarding test and a sexual test, after which a male and female were kept together until the female became visibly pregnant. Late in their pregnancies, the females were separated from their mates and placed in a maternity cage which was 1 sq. ft. in area and 6 in. high. Each cage was provided with a 4-in. cubic nest box containing a single entrance 1 in. in diameter. Most females bore their young 2 to 4 days after separation from their mates. Eight females and their litters in each subspecies were examined.

Procedure.—The maternal and behavioral development tests were given each day until the young mice were 30 days old. Three tests were given to the mothers and the physical and behavioral development of the young were recorded.

1. Defense of young. The young mice were removed from the nest box with a pair of 10-in. forceps. During their removal, the behavior of the mother was evaluated by a check list scored on the basis of *0* for no attention to the forceps, *1* for nosing or pushing the forceps, *2* for mildly and infrequently biting the forceps, and *3* for savagely attacking the forceps. After removed from the nest, the young were examined for their behavioral development (described later).

2. Retrieving response. The entire litter was returned to the cage at the corner farthest removed from the nest box. After the young were returned, the mother usually began to retrieve one young at a time until all were in the nest box. The time taken to retrieve each young was recorded. Only the retrieving times for the first three young are reported here, because the size of the litters varied. Retrieving times for all three young and for each young were used in the analysis.

3. Reactions to male. After the mother had retrieved young, an adult male of the same subspecies was introduced to the cage and kept there for 5 minutes. This test was given on alternate days and usually about three males were alternated among the females being tested at that time. The first introduction of a naïve male was different from subsequent introductions because the male showed no initial fear of the female. After one or two introductions, the males became very submissive to the attacks of the females. The latency, frequency and duration of attacks made by the females upon the males were recorded.

4. Development of young. While the young were removed from the nest, several measurements were made of their physical and behavioral development:

a. Weight. Each litter was weighed as a group to the nearest 0.01 gm.

b. Pelage. The day of the first appearance of both dorsal and ventral fur was recorded.

c. Teeth. The first appearance of lower and upper incisors was recorded.

d. Eyes. The first day the litter had their eyes open was recorded.

e. Righting response. After the young mice were weighed and examined for their physical development, they were placed inverted upon a level, smooth surface. In this position the young mice attempted to right themselves and come to rest on their ventral surface. The first day of appearance of three stages in the development of the righting response was recorded: (1) Torsal twist: the first day the mice twisted their bodies in an attempt to right themselves; (2) first successful righting response in which the mice came to rest on their ventral surface; (3) immediate righting: the first day they were able to gain their feet immediately upon being inverted.

f. Climbing ability. Each young mouse was placed upon a 4-in. square wire screen of ¼-in. mesh. The screen was then slowly rotated until it was vertical and finally upside down. The ability of the young mouse to cling to the screen and move about on it during the rotation of the screen was recorded. Young

mice fell off the vertical and inverted screen before older mice. As the mice matured, they were able to go over the edge from the bottom of the screen to the top. The first day they were able to perform this task was also recorded.

g. Agonistic behavior. As the young mice matured they began to resist being picked up by the forceps when removed from the nest box. Usually this resistance was passive at first, with the mice falling over on their backs and pushing at the forceps with their feet. Later they actively fought the forceps by biting them. The first day each of these two patterns of behavior occurred was recorded.

h. Jumpiness. Timidity or irritability of the mice increased with age. They began to jump off the screen or out of the hand, or leap away when they were picked up. Although it was difficult to obtain a quantitative measure of this behavior, a description is presented in order to indicate the gross subspecific differences.

A motion picture record of representative samples of these behavior patterns was presented before the Section on Animal Behavior and Sociobiology of the Ecological Society of America at the AIBS meeting in Storrs, Connecticut, 1956.

RESULTS

Individual differences among the eight mothers of both subspecies were often extreme, thus masking subspecific differences which appeared typical for the subspecies. Frequently, the extremes of maternal patterns included aberrant behavior, such as excessive carrying of young in circles about the cages until the underparts of the young developed scars from the teeth of the mother. On the other hand, some types of behavior were remarkably consistent for each subspecies.

Defense of young.—The *bairdi* mothers defended their young significantly more than did the *gracilis* mothers ($P<0.001$; Mann-Whitney U test) when the young were being removed from the nest boxes (Fig. 1). The *bairdi* mothers savagely attacked the forceps, bit them frequently, and often held on to them so firmly with their teeth that they could be raised off the floor of the cage. The usual timidity displayed by both subspecies was lacking during lactation. The *gracilis* displayed little fear during the removal of the young, but usually did not attack the forceps. They often left the nest box and then turned about, stuck their heads through the hole and watched the removal without interfering. Sometimes the *gracilis* mothers grasped the young and pulled them loose from the forceps. Despite this attention to the young, they rarely attacked the forceps as did the *bairdi* mothers.

Figure 1 illustrates the differences of the two subspecies in the mean scores received by the mothers each day. From the graph, it can be seen that the defensiveness of *bairdi* diminishes after the fifteenth day and subspecific differences disappear. When the young were about 15 days old, they began to defend themselves, and the mother usually abandoned them. Frequently, 15-day-old young were not in the nest box and the mother had no occasion to interfere in their removal.

Retrieving response.—Several measures were made of the retrieving response: First, the interval between returning the young to the cage and the time the first young was retrieved, then the interval between the first and second young, and finally that between the second and third young. Second, the accumulated time to retrieve two and three young. This offered five possibilities for differences to appear between the two subspecies. None of them showed any significant differences when measured by the Student-Fisher *t*-test. Figure 2 illustrates the mean retrieving time of the mothers in retrieving the first young during their development from birth to 18 days of age. Although the figure shows no significant subspecific differences in retrieving time, it does illustrate that the latency to retrieve decreases as the young become older. The graph suggests that the mothers acquire the proficiency to retrieve after their first few experiences. The retrieving latency drops rapidly during the first five days for the first young retrieved, but not for the second and third young retrieved. The second and third young are retrieved immediately after the first young is taken to the nest even on the first day. These results agree with those of Beach and Jaynes (1956) in the retrieving behavior of the white rat.

Individual variability in retrieving behavior was extensive. Some mothers picked up the young very carefully, manipulated them in their forepaws until they had a good grasp of them in their incisors. Other mothers grabbed the young anywhere on the body and hauled them to the nest. Most mothers appeared to carry their offspring by grasping them on the underparts as described by Huestis (1933), but others were picked up by the nape and rump. Some mothers took the young directly to the nest box; others circled the cage with them before depositing them inside. Some mothers even took the young in and out of the nest box several times before depositing them there. Often one young

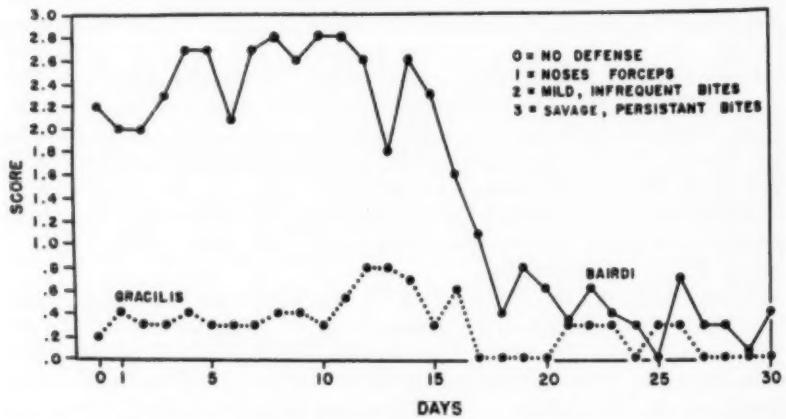

FIG. 1.—Defense of young. Daily mean rating scores of *P. m. bairdi* and *P. m. gracilis* in response to the forceps used in removing young from nest box.

was picked up, moved a short distance, dropped, and another one was picked up. On the day of birth, it was not uncommon to see the mother attempt to build a nest over the young or protect them with her body rather than retrieve them. Most mothers came out and inspected the cage after the last young had been retrieved. As the young grew older and more capable of returning to the nest box themselves, some mothers no longer attempted to retrieve them, while others carried the young into the nest box, even when they immediately ran outside again. Often the grown young resisted the attempts of the mother to retrieve them. If the young successfully resisted, the mother left them and went on to a different young.

Reactions to male.—Subspecific differences in the reaction of the mother to a male were outstanding. In all three measures of aggressiveness of the female, the *gracilis* proved to be significantly more hostile to a male than did the *bairdi*.

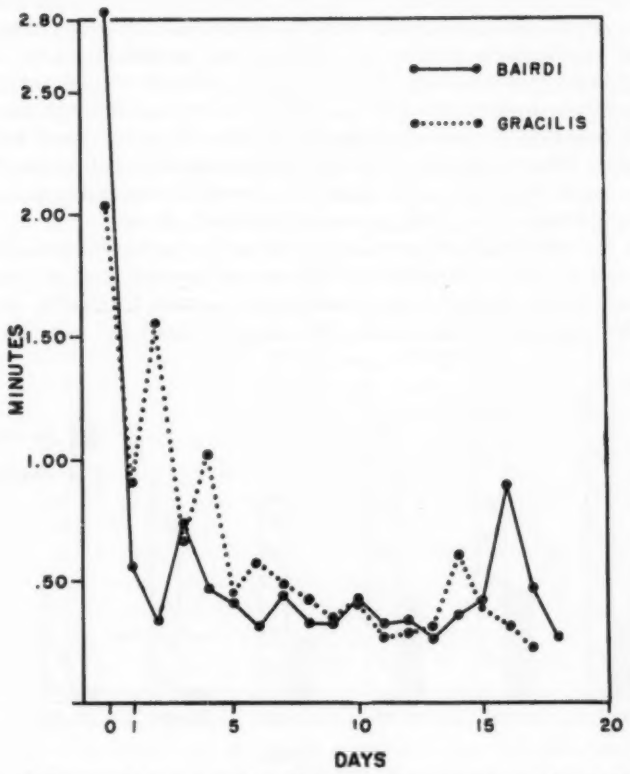

FIG. 2.—Daily mean latency to retrieve first young of a group to nest box in *P. m. bairdi* and *P. m. gracilis*.

The mean number of attacks per female, the mean latency to attack the male, and the mean duration of attacks had only one case of overlapping between the two subspecies. A histogram of the frequency of attacks over the 30-day period studied is presented in Fig. 3. Although the *gracilis* were more aggressive toward the introduced male, the *bairdi* mothers were by no means friendly. Both subspecies violently attacked the male. In Fig. 3, the frequencies are grouped in 5-day periods because the male was introduced only on alternate days. However, there was no striking change in the antagonism shown toward the male over the 30-day period, except in the diminished activity of *bairdi* mothers after the young were 20 days old. The mothers' reactions to the male may be a form of defense of the young similar to their reactions to the forceps during the removal of the young from the nest box. However, the amount of aggression displayed in both tests was reversed in each subspecies. The *gracilis* failed to attack the forceps, but were severe in their attacks upon the introduced male.

Females without a litter usually do not react aggressively toward an introduced male. If a male, usually the mate, is caged with a female prior to parturition, the female rarely attacks him after she has produced a litter. In fact, father and mother often occupy the nest together with the young, and the father may even share in their care (Horner, 1947). This amenable behavior was in sharp contrast to that which a lactating female showed toward a male introduced to her cage. Even her former mate was savagely attacked and beaten. This behavior suggests that lactating females may display territoriality toward individuals which are not in continuous association with them.

When the male was first introduced to the cage, the typical behavior of the female was to attack immediately without any investigation or caution. A naïve male rarely repulsed such a fierce attack; instead, he tried to escape the aggressive approach of the female. The female chased the male relentlessly

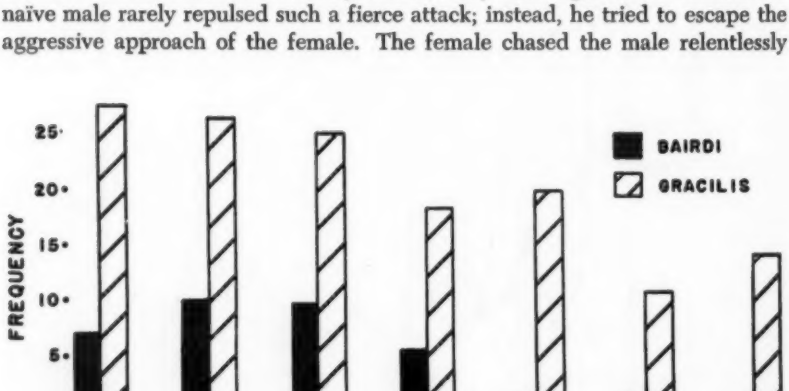

FIG. 3.—Mean number of attacks female makes upon male introduced into cage for 5 min. over a period of 5 days.

until he showed signs of submission and fell over on his back defensively. Then she stood over him and bit him at intervals until he leaped away again. In fights among males, the submissive posture of lying passively on the back rarely stimulates the aggressive mouse to continue the attack. In females, the submissive posture did not inhibit the attack of the female as she continued to bite the passive male until he leaped away. After a series of introductions the males usually developed a pattern of behavior which reduced the effectiveness of the females' attacks. Most often they hid on the food hopper and ran around it away from the female or tried to repulse her by pushing at her with their forepaws. The effectiveness of this defense against the females may account for some of the subspecific differences in frequency and duration of attacks. The tails and paws of the males were frequently bleeding when they were removed from the cage after 5 minutes. Only on rare occasions did the male ever attempt to fight back.

During the frequent attacks upon a male, a mother often pounced upon her young, particularly after the latter were old enough to run about the cage. Once the mother identified the young mouse as her offspring, she left it and returned to attack the male. On occasions she appeared to punish her young and localize them in a corner of the cage to prevent them from interfering with her attacks. Young *gracilis* at 25 days of age often joined their mother in attacking the male. Young *bairdi* were not observed attacking the male. Usually, the young *bairdi* hid in the nest box during the presence of the male.

Development of young.—Behavioral development depends to a certain extent upon physical maturation and some measures of physical growth were included in this study. During the study, approximately 45 young of each subspecies were examined. The mean litter size in each subspecies was 5, with a range from 3 to 7. Although individual differences in growth rate existed within each litter, the litter was the unit measured. Means were calculated or estimated for each litter. For example, if in a litter of five one mouse had its eyes open on the eleventh day and four on the twelfth day, the twelfth day was selected as the mean day of opening the eyes.

The following measures of development represent only a few of those which may be classified as sensory, motor, psychological, and social development (Williams and Scott, 1953).

Weight.—There were no significant subspecific differences in mean individual growth rates on any of the 31 days the mice were weighed. The greatest mean difference was 1.1 gm. on the twenty-fifth day when *bairdi* weighed more than *gracilis*. No striking weight differences appeared in six subspecies of *maniculatus* studied by Dice and Bradley (1942) until the mice were about 45 days old, which is beyond the age examined in the present study. Although there were no significant weight differences between the two subspecies in this study, the relative differences in weight changes indicate behavioral differences which recurred throughout the study. During the first 19 days, the mean weight of *bairdi* was persistently less by 0.1 to 0.5 gm. than *gracilis* (Fig. 4). At 19 days

there was no difference and from 20 to 30 days the *bairdi* weighed persistently more than the *gracilis*, reaching the greatest weight difference of 1.1 gm. at 25 days of age. At 30 days of age the difference had again decreased to only 0.4 gm. These weight records may be interpreted in terms of nutrition. The *bairdi* apparently shifted to solid foods about five days before the *gracilis* and consequently grew faster until the *gracilis* began to eat solid food, at which time (25 days) the differences again decreased. This indirect evidence supports the general finding that *bairdi* develop faster than *gracilis*.

Pelage and pigmentation.—Pigmentation of the skin in young *bairdi* was nearly complete at about four days of age ($\bar{x} = 3.6$) while in *gracilis* it was not complete until about five days ($\bar{x} = 5.4$). The darker pelage of the adult *bairdi* was indicated early in their development. The differences in age of first complete pigmentation were significant at the 0.01 level when tested by the Mann-Whitney *U* test. Likewise, the dorsal pelage of *bairdi* macroscopically appeared about one day in advance of *gracilis* ($P < 0.01$).

Teeth.—Although the eruption of the lower incisors of *bairdi* preceded that of *gracilis* at about five days, the differences were not significant. The difficulty involved in making this measure on living mice tended to reduce its reliability. Age differences in the first day of appearance of teeth and other characteristics are shown in Fig. 5.

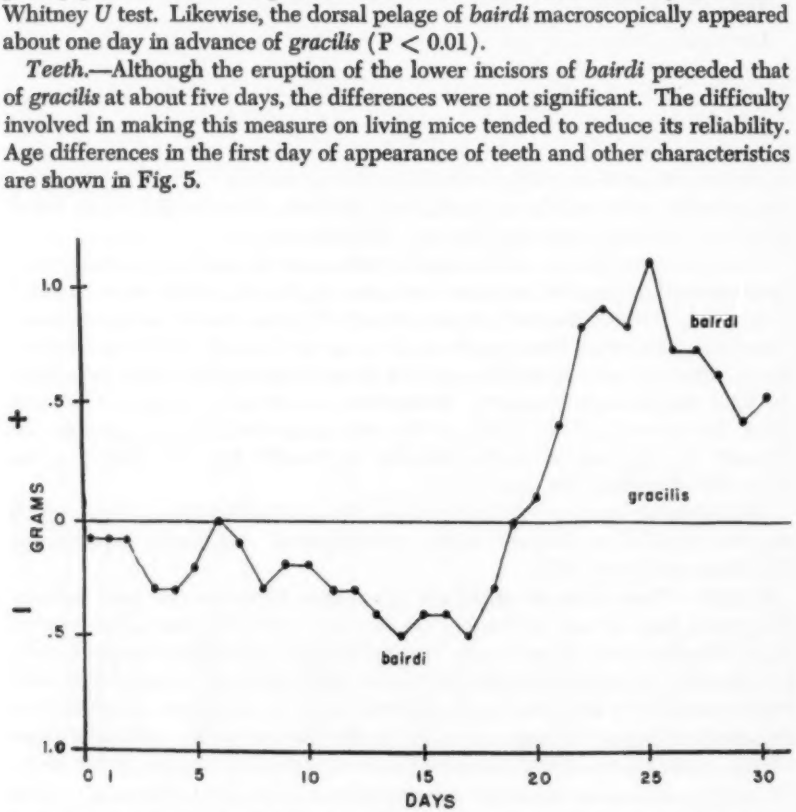

FIG. 4.—Difference in weight. Daily mean plus and minus deviations in weight of *P. m. bairdi* from *P. m. gracilis*.

Eyes.—As the mice matured, the differences in rates of development between the two subspecies increased. The eyes of young *bairdi* first opened about 12 days of age ($\bar{x} = 12.1$), while young *gracilis* opened their eyes about five days later at 17 days ($\bar{x} = 16.8$). There was no overlapping of this characteristic in the two subspecies. The latest time at which *bairdi* opened their eyes was at 13 days and the earliest time at which *gracilis* opened their eyes was at 15 days.

Righting response.—Behavioral characteristics are often difficult to measure and the subspecific differences presented here are an approximation. In general, *bairdi* preceded *gracilis* in behavioral capacities by about one day in the earlier stages, and this difference increased with age. There was no significant difference between the two subspecies on the day they first exhibited the torsal twist or were capable of righting themselves (Fig. 4). However, when they were first able to right themselves immediately, *bairdi* significantly preceded *gracilis* (*bairdi* $\bar{x} = 7.2$ days; *gracilis* $\bar{x} = 8.9$ days; $P < 0.01$).

Climbing ability.—The climbing performances of these two subspecies as adults has shown that *gracilis* is superior to *bairdi* (Horner, 1954). This adult ability was not indicated in the rate of maturation, for young *bairdi* tended to show more climbing skill earlier than *gracilis*. Differences in the rate of maturation in climbing were not significant, however. Perhaps *gracilis* matures more rapidly in climbing ability than it does in other behavioral characteristics. In general, both subspecies showed marked propensities to climb and to cling to the screen, regardless of their position on it. The most striking difference observed was the stronger tendency of *gracilis* to cling to the screen after they began to lose their hold. Although young *bairdi* demonstrated their ability to hang on an inverted screen, they did not hesitate to drop from it if they tempor-

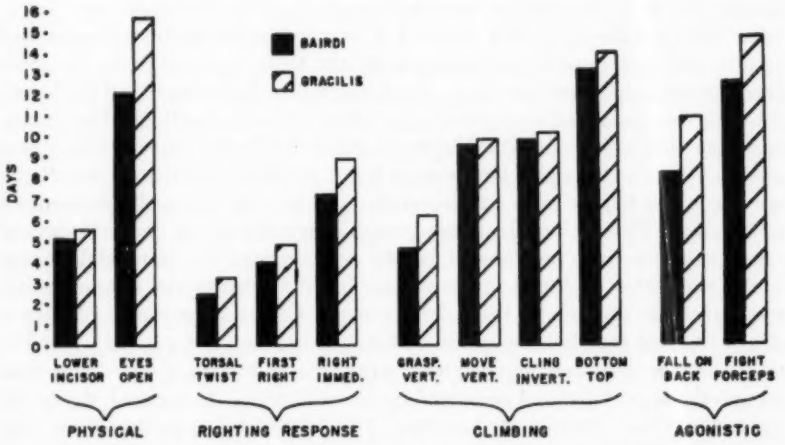

FIG. 5.—Development of young. Mean day of first appearance of physical and behavioral characteristics in *P. m. bairdi* and *P. m. gracilis*.

arily lost their footing. In contrast, young *gracilis* clung to the screen tenuously and made every attempt to regain their hold after they began falling. These differences were most apparent after 12 days of age.

Agonistic behavior.—This behavior is characterized by aggressive or defensive fighting or by escape behavior (Scott, 1956). The two measures of the development of this behavior showed that the defensive attitude of falling on the back and pushing with the feet appeared several days prior to the active fighting and biting of the forceps when the animal was picked up. On the first day of appearance for both of these measures, *bairdi* preceded *gracilis* by about two days. The Mann-Whitney *U* test indicated that the differences were significant at the 0.01 level of confidence. The median day of first appearance of falling on back was 9 for the *bairdi* and 11 for *gracilis*. The first appearance of fighting was 12 days for *bairdi* and 14 days for *gracilis* (Fig. 5).

Jumpiness.—A suitable technique for measuring jumpiness, temperament (McCabe and Blanchard, 1950), or nervousness (Horner, 1954) was not developed during the study. However, this characteristic was noticeably different in the two subspecies and deserves description. Differences in the jumpiness of adults of these two subspecies have been described by Horner (1954) who says that *gracilis* "movements are leisurely in contradistinction to the . . . more cautious, deliberate ones of *bairdi* . . . . *Bairdi* mice tend to be timid and nervous." These differences in behavior were evident early in the development of the two subspecies, although both passed through a stage of heightened excitability. In young *bairdi* the jumpiness, characterized by aimless leaps from any object at any height in a completely uninhibited fashion, reached its peak at about 15 days. This random, wild behavior continued throughout the 30 days of testing, but tended to change in character at about 22 days of age. The change was from the aimless, repeated jumps to more deliberate and "calculated" jumps of the wild adult. Instead of leaping into the air from the elevated screen, and then immediately jumping off the table onto the floor, the older *bairdi* apparently leaped for some object, and when they missed and landed on the table they ran about trying to escape before falling to the floor. The change was from aimless, uncontrolled leaping to timid, deliberate leaping. The young *gracilis* also went through a jumpy stage but it occurred later than in *bairdi*, did not become as intense as in *bairdi* and changed into the "leisurely" movements of the adult. The peak of the jumpy period in *gracilis* was at about 20 days of age. At this age, only one litter of *gracilis* demonstrated the same wild leaping as did most litters of *bairdi*. Some *gracilis* failed to display any jumpiness and were tractable throughout their development. Others were jumpy for just a day or two and then became gentle and easy to handle. The *gracilis* seemed to respond to the daily handling and were quite tame at 30 days of age. They often sat quietly on my hand and permitted me to stroke them. In contrast, the *bairdi* showed no effect of the early handling. I had difficulty in getting them onto my hand and if I did they immediately leaped off or ran up my arm to escape.

The beginning of the jumpy stage followed shortly after the eyes opened,

which suggests that it develops from a perceptual awareness of the environment. In the domestic house mouse, jumpiness appears almost simultaneously with opening of the eyes at about 12 days of age (Williams and Scott, 1953). Neural-motor coordination is sufficiently developed at this age to permit a violent response to the environmental stimuli impinging upon the young mouse for the first time. It is possible that neural inhibition has not matured sufficiently to prevent random leaping at this early age or that negative reinforcement derived from the painful experiences in falling and leaping were not sufficient for learning to occur. These problems are currently under investigation.

DISCUSSION

The mice used is this study are subject to the errors of sampling commonly found in biological studies. They do not necessarily represent the entire subspecies of which they are members. The *bairdi* were derived from a large number of wild-caught mice but the *gracilis* resulted from the breeding of only a few wild-caught specimens (see McIntosh, 1955). In addition to these small samples, generalizations to the entire subspecies must be limited by the fact that some artificial selection must have occurred during the time they were bred and raised in the laboratory. Although no conscious selection was made, except possibly for fertility, it is likely that some of the traits measured in this study were affected by selective breeding. Despite these possible errors of sampling and unconscious selective breeding, the differences found in the characteristics measured are subspecific. A random selection of the combined subspecies would not have produced the consistent differences found between the two subspecies. The differences are real; only the generalizations drawn from them are limited. The fact that another investigator (Horner, 1954) has described similar behavior in other specimens of the two subspecies indicates that some generalizations to the natural populations can be safely made.

The absence of subspecific differences in the time to retrieve the young suggests that gross deviations in retrieving would soon be eliminated by increased selection. Most observed deviations indicated an over-developed retrieving response. The selective forces in the environments of the two subspecies may thus be similar in respect to retrieving behavior. The extent of these selective forces has been indicated by Curio (1955) who proposed that the similar methods for carrying young in different rodent genera may be the result of convergent evolution. Mothers that tend to retrieve less rapidly or less efficiently than those in this study might expose their offspring to such severe selection that any transmission of this trait from one generation to the next would be eliminated.

In contrast to the retrieving behavior, the defense of young and the reactions to a male, which may also be considered a defensive response in chasing the male from the nest site, were remarkably different in both subspecies. While *bairdi* mothers attacked the forceps more savagely than did *gracilis*, the latter attacked the introduced male more actively. Interpretations of these differences from the viewpoint of adaptations made to the environment first suggest

that defense of young is important to survival, but selection pressure is not as high as that in retrieving. More variability can exist within the broader limits of selection than is possible for retrieving. A second interpretation is that the different environments of *bairdi* and *gracilis* impose different requirements on the defensive behavior of the mothers. In *bairdi*, the mother's response to the forceps suggests that she must defend her young against non-species members more often than against species members. Perhaps the grassland environment and more vulnerable nest sites of *bairdi* expose the young to frequent encroachments of other species of mice (principally *Microtus*), shrews, ground squirrels, and snakes (Dice, 1932; Blair, 1940; Howard, 1949). In contrast, *gracilis* may be able to locate their nests in places less exposed to interference by other species (Dice, 1925; Manville, 1949), but more exposed to interference from species members. Consequently, *gracilis* mothers display more aggression toward strange males than do *bairdi* mothers. It is important to note that subspecific differences in the reaction to a male were quantitative, while qualitative differences appeared in the mothers' reactions to the forceps.

Perhaps the most striking difference in these two subspecies is the differential rates of development. McCabe and Blanchard (1950) describe similar differences between the species *maniculatus* and *californicus*. In the present study of two subspecies of *maniculatus*, one subspecies (*bairdi*) matures physically and behaviorally much more rapidly than does the other subspecies (*gracilis*). In some characteristics, such as opening of the eyes, the difference in maturation may be as much as five days, while in other characteristics the differences are less extreme. The adaptive significance of these differential rates of maturation is difficult to assess, except possibly that young *bairdi* are perhaps more vulnerable to selection in the nest than young *gracilis*. Nice *et al.* (1956) discuss the survival values of differential rates of development in different genera of mammals. Regardless of the cause for these subspecific differences in growth, it appears likely that the rapid maturation of *bairdi* or the slow maturation of *gracilis* may affect their adult morphological and behavioral characteristics. The comparative material of McCabe and Blanchard (1950) in *Peromyscus* and of Frank (1954) in microtines, as well as the material reported here, suggests that slow maturation is at least correlated with, if not the cause of, "tameness" or a heightened threshold of irritability. Since it is difficult to control maturational rates experimentally, comparative studies of different subspecies and species in this genus may provide some correlation between rate of maturation and adult form and behavior.

SUMMARY

The maternal behavior and development of behavior in the young of eight *Peromyscus maniculatus bairdi* and eight *P. m. gracilis* were compared in a series of laboratory tests. The tests given to the mothers were: (1) defense of young against the forceps used in removing young from the nest box; (2) time of retrieving young into nest box; and (3) reactions toward a male introduced into the cage with the young. Physical measurements of weight, pelage growth, eruption of teeth and opening of eyes were made on the development of the

young. Behavioral measures of development included (1) righting response, (2) climbing ability, (3) agonistic behavior and (4) jumpiness. The tests began on the day of birth and proceeded each day until the young were 30 days old.

In defending the young against forceps, *bairdi* mothers were more aggressive than *gracilis* mothers, which usually avoided the forceps. No differences between subspecies were found in the retrieving response. When a male was introduced into the cage, the *gracilis* mothers attacked the males sooner, more frequently, and for longer periods than did the *bairdi* mothers.

The physical and behavioral development of *bairdi* progresses more rapidly than that of *gracilis*. At the age when the eyes open, *bairdi* precedes *gracilis* by five days. Concurrent with the opening of the eyes, the young mice become highly irritable and aimlessly jump from any height. This jumpiness persists longer in *bairdi* than in *gracilis* and was not completely inhibited in *bairdi* at the end of testing. *Gracilis* exhibit less jumpiness, for a shorter period of time, and soon become gentle and "cautious."

The adaptive significance of these differences is discussed in relation to the type of environment utilized by both subspecies. Differential maturation rates in the two subspecies may offer an explanation for adult differences in behavior.

LITERATURE CITED

Beach, F. A. and J. Jaynes. 1956. Studies on maternal retrieving in rats: II. Effects of practice and previous parturitions. Amer. Nat., 90: 103–109.

Blair, F. W. 1940. A study of prairie deer-mouse populations in southern Michigan. Amer. Midl. Nat., 24: 273–305.

———. 1942. Size of home range and notes on the life history of the woodland deer-mouse and eastern chipmunk in northern Michigan. Jour. Mamm., 23: 27–36.

Curio, Eberhard. 1955. Der Jungentransport einer Gelbhalsmaus (*Apodemus f. flavicollis* Melch.). Zeit. Tierpsychol., 12: 459–462.

Dice, L. R. 1925. The mammals of Marion Island, Grand Traverse County, Michigan. Occ. Pap. Mus. Zool., Univ. Mich., 160: 1–8.

———. 1932. The prairie deer-mouse. Cranbrook Inst. Sci. Bull., 2: 1–8.

——— and R. M. Bradley. 1942. Growth in the deer-mouse, *Peromyscus maniculatus*. Jour. Mamm., 23: 416–427.

Frank, Fritz. 1954. Beitrag zur Biologie, insbesondere Jugendentwicklung der Schneemaus (*Chionomys nivalis* Mart). Zeit. Tierpsychol., 11: 1–9.

Harris, V. T. 1952. An experimental study of habitat selection by the prairie and forest races of the deermouse, *Peromyscus maniculatus*. Contr. Lab. Vert. Biol., Univ. Mich., 56: 1–53.

———. 1954. Experimental evidence of reproductive isolation between two subspecies of *Peromyscus maniculatus*. Contr. Lab. Vert Biol., Univ. Mich., 70: 1–13.

Hooper, E. T. 1942. An effect on the *Peromyscus maniculatus* rassenkreis of land utilization in Michigan. Jour. Mamm., 23: 193–196.

Horner, B. E. 1947. Paternal care of young mice of the genus *Peromyscus* Jour. Mamm., 28: 31–36.

———. 1954. Arboreal adaptations of *Peromyscus*, with special reference to use of the tail. Contr. Lab. Vert. Biol., Univ. Mich., 61: 1–85.

Howard, W. E. 1949. Dispersal, amount of inbreeding, and longevity in a local population of prairie deermice on the George Reserve, southern Michigan. Contr. Lab. Vert. Biol., Univ. Mich., 43: 1–50.

Huestis, R. R. 1933. Maternal behavior in the deer mouse. Jour. Mamm., 14: 47–49.

Manville, R. H. 1949. A study of small mammal populations in northern Michigan. Misc. Publ. Mus. Zool., Univ. Mich., 73: 1–83.

McCabe, T. T. and B. D. Blanchard. 1950. Three species of *Peromyscus*. Rood Assoc., Santa Barbara, Calif., pp. v + 136.

McIntosh, W. B. 1955. The applicability of covariance analysis for comparison of body and skeletal measurements between two races of the deermouse, *Peromyscus maniculatus*. Contr. Lab. Vert. Biol., Univ. Mich., 72: 1–54.

Nice, M. N., C. Nice and D. Ewers. 1956. Comparison of behavior development in snowshoe hares and red squirrels. Jour. Mamm., 37: 64–74.

Scott, J. P. 1956. The analysis of social organization in animals. Ecology, 37: 213–221.

Williams, E. and J. P. Scott. 1953. The development of social behavior patterns in the mouse, in relation to natural periods. Behavior, 6: 35–64.

Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine. Received January 21, 1957.

RANGE OF MOVEMENT OF SOME MALAYAN RATS

By John L. Harrison

Although accounts of experiments involving the trapping and retrapping of marked rodents are now numerous, no such studies seem to have been made of the many species of rats in Southeast Asia. Experiments of this sort have recently been carried out in Malaya on rats which are the hosts of the chiggers which transmit mite-typhus (scrub-typhus). Unlike most such studies, interest was centered rather on differences between species than on differences between individuals of the same species, and a method was sought of expressing an "average" home range for such species. In attempting to do this it became clear that the customary methods of estimating home range, such as those summarized by Stickel (1954), were not in fact applicable to the problem, since the "home range," as usually understood, could not be exactly delimited. The concept of the home range has, therefore, been replaced, for this purpose, by the concept of a series of probability contours surrounding a center of activity, and what appears to be a new way of calculating and expressing the result has been evolved.

SPECIES CONCERNED

The major hosts of the trombiculid mites which convey mite-typhus are, in Malaysia, rats of the genus *Rattus*. Some account of the various mammals involved has previously been given in these pages (Harrison and Traub, 1950) and elsewhere (Audy and Harrison, 1954), while a detailed study of their habitat preferences has been published recently (Harrison, 1957). The species involved in the present account are:

Rattus jalorensis (Bonhote), Malaysian wood rat. A member of the white-bellied *Rattus rattus* group, confined to cleared land and secondary forest, with a decided preference for the edges of woodland.

Rattus argentiventer (Robinson & Kloss), ricefield rat. Also a member of the *Rattus rattus* group, confined to grassland and ricefields.

Rattus exulans (Peale) = *R. exulans concolor* (Blyth), little Burmese rat. A small rat of grassland and scrub.

Rattus mülleri (Jentink), Miller's giant rat. A forest rat of damp valley bottoms.

Rattus sabanus (Thomas), long-tailed giant rat. A forest rat of higher ground.

Rattus rajah (Thomas), Rajah spiny rat. The name is here used to include two forms, *R. pellax* (Miller) and *R. surifer* (Miller), which occur together and are ecologically indistinguishable forest rats.

Rattus whiteheadi (Thomas), lesser spiny rat. A small rat of forest and secondary forest.

METHODS

The methods and experimental areas have been described in detail by Audy and Harrison (1954). In brief each experimental area, which was chosen to sample some particular habitat, was marked out with a rectangular grid, usually at 20-meter intervals. Traps were laid for a working week (4–5 nights) at each point, rows of points being sampled in turn, so that every point was sampled in a cycle of from five to eight weeks. Details of the methods of trapping varied from experiment to experiment, but were broadly similar, with the exception of the "Spooner Road" area which was trapped on a different plan. This particular area was subdivided into a number of smaller areas, each of which was sampled, in turn, by a double line of ten traps.

Trapped rats were brought back to the laboratory for detailed examination (including the collection of parasites) and marking where necessary. They were released again on the same or following day, at the point where they had been trapped.

ESTIMATION OF RANGE

When these experiments were commenced it was assumed that each individual rat had a home range or a territory, of the sort described so vividly by Hediger (1950), which could be estimated by such methods as those enumerated by Stickel (1954). At first it was assumed that such results as the distributions recorded in Fig. 1 indicated some kind of defended territory, but the complete overlap of the ranges of different specimens of the same species and sex, such as that shown in Fig. 2, ruled out this explanation. Later it was assumed that, even though no mutually exclusive territories were revealed, it would be possible to delimit some kind of "home range" as defined by Burt (1943) to which the rat *normally* restricted its wanderings, and some estimates of the diameters of such ranges were published in an annual report (I.M.R., 1952).

The fallacy of applying "home range" concepts to these rats was revealed when a close study of available results was made to attempt a definition of the expression *normally*. In fact no evidence could be found that the rat did restrict its range. What could be described as boundaries to a range, such as those exhibited in Fig. 3, were found to occur only along the boundary of an ecological habitat. Within a uniform habitat the rat seemed to range over a boundless area—

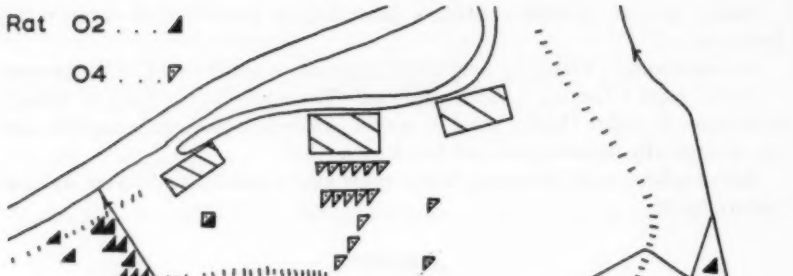

FIG. 1.—Map of the distribution of trappings of two specimens of *Rattus jalorensis* between August, 1952 and April, 1953. Each triangle represents a trapping, lines of triangles meaning repeated trapping at the same point. The area is of grassy scrub between roads and houses (cross-hatched). The rats appear to exhibit territorialism.

that is to say, not that the rat was equally likely to appear in any part of the area trapped, but that no sharp boundary could be distinguished. It was possible to find a "center of activity" for the individual (Hayne, 1949) and its

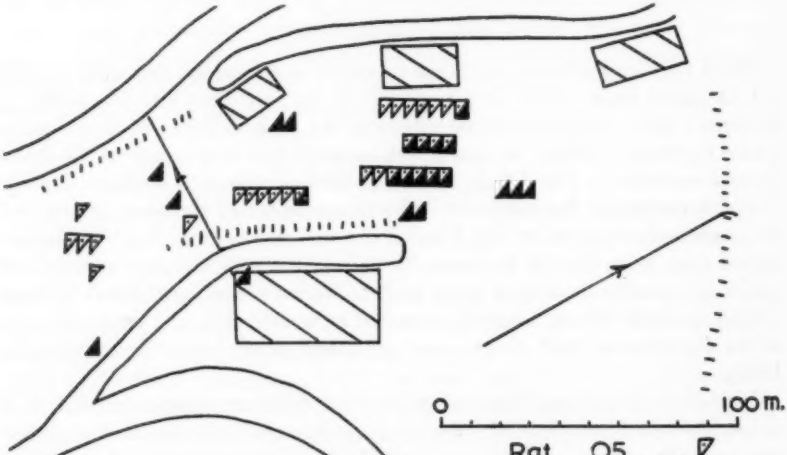

FIG. 2.—The distribution of trappings of two male *R. jalorensis* in the same area as Fig. 1, between September, 1952 and June, 1953, showing the complete interpenetration of ranges.

chance of being trapped at any distance away from the center appeared to diminish continuously as the distance increased. The center of activity, it should be appreciated, is a purely mathematical concept, being the geometrical center of all points at which it was trapped.

Probability zones.—The concept of a "home range" has therefore been abandoned in favor of the idea of a center of activity surrounded by a series of concentric probability zones within which the rat spends varying proportions of its time. These zones may be looked upon as a series of annuli within which the rat spends proportions of its time which decrease as the radius increases, as indicated by Fig. 4 which shows zones in which the rat can be expected to spend successively 50, 30, 15 and 4 per cent of its time, 1 per cent being spent outside the largest circle. An alternative way of looking at them, more convenient for calculation, is to consider the total zone within a circle so that, as the radius of the circle increases, the total time spent within it increases, but the increase is not directly proportional to the area of the zone, and the 100 per cent zone, within which the rat spends all of its time, must be regarded as infinite. These are the circles in Fig. 4 labeled 50, 80, 95 and 99, representing those percentages of the total time.

If we trap the area uniformly, and if the chance of being trapped varies di-

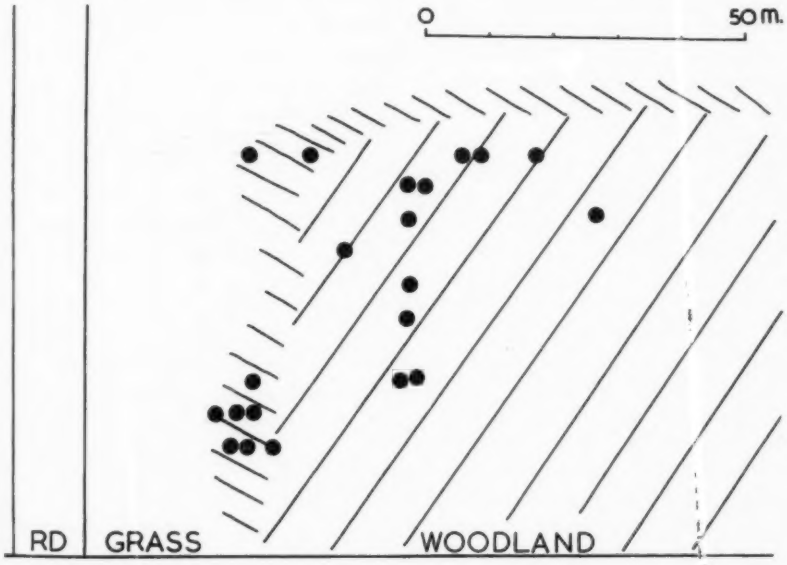

FIG. 3.—The distribution of trappings of a specimen of *R. whiteheadi* showing a range bounded by an ecological boundary. The map represents the edge of a wood by a road. Course cross-hatching represents woodland (secondary forest), finer cross-hatching the dense scrub forming the edge of the woodland. Absence of shading represents grass.

rectly with the time spent in the area, then our probability zones for time are the same as those for trapping, i.e., the circle within which the rat spends 50 per cent of its time is the same as the one within which there is a 50 per cent chance of its being trapped. Figure 5 shows a series of such zones, derived from the calculations given below, superimposed on a map of the distribution of captures of an individual *Rattus exulans* trapped 11 times. The zones are centered on the calculated center of activity of the rat, and the numbers of trappings observed and expected within each zone are: 11 (9.9), 10 (8.8), 8 (7.7), 7 (66), 7 (5.5), 7 (4.4), 4 (3.3), 2 (2.2) and 1 (1.1). The agreement with expectation is remarkably close. These zones are shown as circles, but of course they are not necessarily so, and will not be so if the habitat is not uniform.

The experiments considered were, however, carried out in substantially uniform habitats and, assuming that the probability zones may be expressed as circles, an attempt has been made to estimate their diameters not for the individual rat, but for the species within that habitat. The information available is, for each individual rat, a distribution map such as Figs. 1 and 2. From a suf-

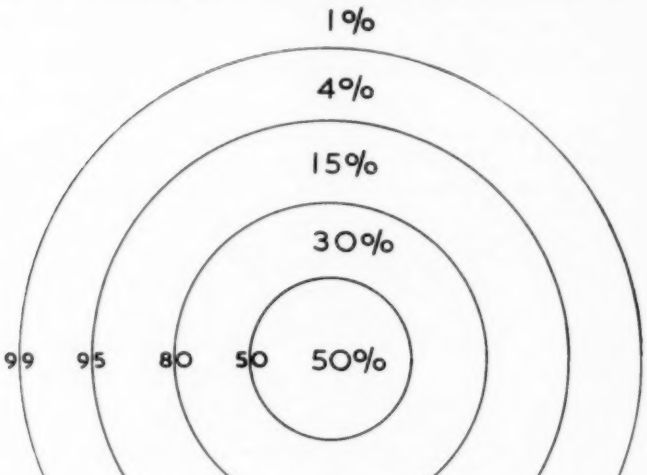

FIG. 4.—Probability zones (based on a normal distribution) about the center of activity of a rat. Percentages indicate the proportion of all trappings to be expected in that annular zone, while the numbered circles represent the cumulative percentage of trappings to be expected within the circle.

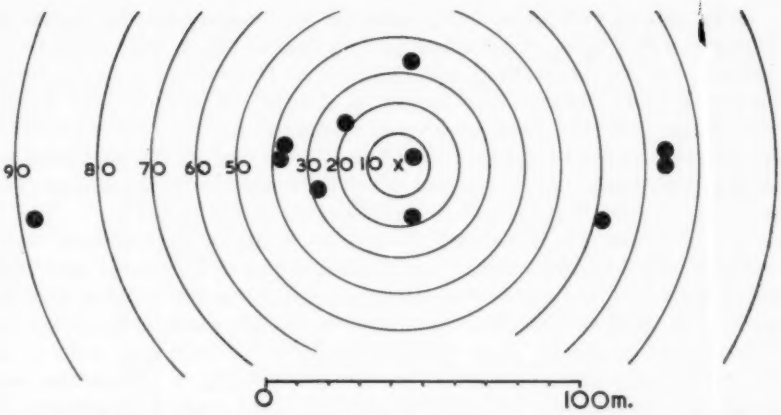

FIG. 5.—Cumulative probability zones, 10–90%, based on a standard diameter of 76 m., superimposed on the eleven recorded trappings of a single *R. exulans*. The center of distribution (marked with a cross) is calculated.

ficiently detailed map (such as Fig. 5) it would be possible to estimate a center of distribution and from it to lay out a series of concentric circles of diameters 20 m., 30 m., 40 m., etc. It would then be possible to record the total number of trappings inside circles of successive diameters. Information of this sort could be assembled for a number of individuals and consolidated to give an average distribution of trapping, as shown in Fig. 6, in which the total number of trappings of eight rats are recorded within circles of diameters increasing by 20-meter intervals.

This could be done, however, only when enough recoveries had been made to give a good estimate of the center of activity; in fact, such information was available for but few rats. The procedure adopted, therefore, was not to calculate a center of activity for each rat, but to measure, with a scale marked in intervals representing 20 m., the number of points which could be included within measurements of 200 m., 180 m., 160 m., etc., and treat these as if they were the numbers included within circles of those diameters. Such measurements were taken for all rats recovered four times or more (to eliminate chance vagrants) and summed for each species and locality. The number which could be included within zero diameter (usually one or two at a central point) was also recorded and deducted from the totals within larger diameters, so that the numbers used for calculation are not in fact numbers of points, but numbers of distances between points*. To make this procedure clear the full records for *Rattus sabanus* (of which very few records were available) is given in Table 1. The last line, deviation, is explained below.

* If we take the distance between two extreme points as the sum of their two radial distances from the center, then the mean of the squares of all such distances will approximate very closely to four times the variance of the points about their mean value, i.e., the square of the "standard diameter" as defined below.

By assembling such figures and plotting the diameters against the number of trappings within them, distributions, such as that in Fig. 6, were obtained to which it was possible to fit an empirical curve. This figure shows the curve for *Rattus mülleri* derived from the results of eight rats, each trapped five or more times. Both the actual number of trappings and the percentage of all trappings are shown on the scale, so it is possible to read off the percentage of all trappings within a given diameter, which is the same as the probability (per cent) that any one trapping will be within a circle of that diameter.

As a control on the efficiency of the method of measuring, a series of eight artificial "trapping distributions," each corresponding in number of trappings to one of the rats, was made up by allotting points on the 400 × 320 m. grid, as used for *R. mülleri*, by means of a series of random numbers tabulated by Fisher and Yates (1943). These artificial distributions were treated in the same way as the real ones, and the results are also shown in Fig. 6. Clearly they approximate a straight line, as would be expected for a random distribution of trapping points, in which the chance of occurrence is directly related to the area.

Transformation of coordinates.—We have now a series of empirical curves from which it is possible to read the probability that a rat of the particular species and habitat will be trapped within a certain distance from its center of activity, or vice versa (such probabilities are summarized in Table 2). These curves, however, are rather awkward to fit and draw, and it is more convenient to have a theoretically ideal curve, so that by transforming the scale of the axes, the points plotted may be made to lie approximately on a straight line.

A convenient and likely distribution is obtained by assuming that the trappings are distributed normally about the center of activity. We would, perhaps, expect a normal surface, but in fact a normal curve gives a better fit (i.e., the probability of trapping at distance x from the center of activity is proportional to the ordinate of a normal distribution at distance x from the mean). A convenient way of expressing this relationship is to say that the probability of trap-

TABLE 1.—*Summary of the number of recoveries of four specimens of Rattus sabanus within circles of successively increasing diameters (in meters) to show the construction of the diagrams*

SPECIMEN NO.	NO. OF RECOVERIES WITHIN DIAMETER							
	0	20	40	60	80	100	120	140
F17	1	1	2	3	4	5	5	6
F18	1	1	1	2	2	2	2	3
F16	1	2	2	2	2	2	2	2
F15	1	1	1	1	2	2	2	2
Total	4	5	6	8	10	11	11	13
Difference	0	1	2	4	6	7	7	9
Percentage	–	11	22	44	67	78	78	100
Deviation	–	.14	.28	.58	.97	1.23	1.23	inf.

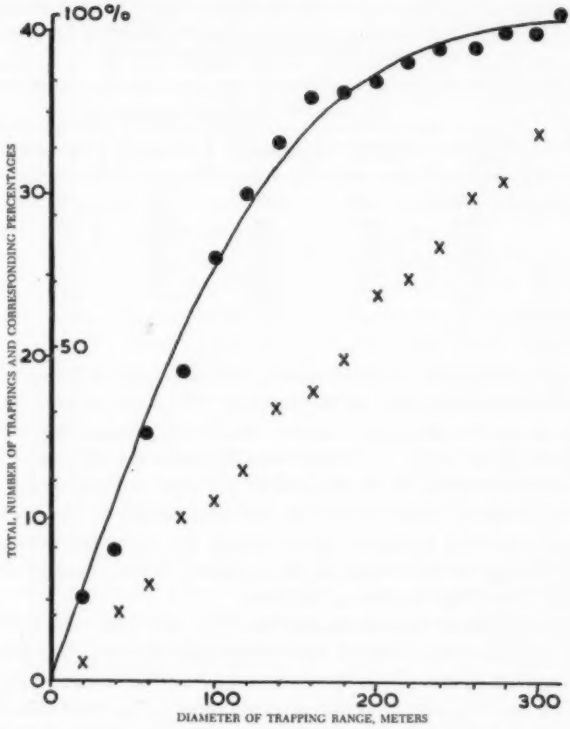

FIG. 6.—Dots: cumulative numbers of trappings of eight specimens of *Rattus mülleri* within circles of the diameter shown. The curve fitted is the cumulative probability that a point will occur within the given distance of the mean of a normal curve of 117 meters. Crosses: the same information based on eight imaginary trapping distributions prepared by allotting trapping points on the same grid from a table of random numbers.

ping within a certain radius is proportional to the probability that a point in a normal distribution shall be within a corresponding deviation. These probabilities are tabulated in detail, for example, in Table 1 of Fisher and Yates (1943)*. The same information is given in more detail, but in a different form, in the table of probits (Table 9), and this table has in fact been used. In Fig. 6 the curve is drawn by taking the standard deviation as 117 meters. The fit is obviously good.

In Figs. 7 to 9, therefore, the diameters are plotted against, not the percentage within this diameter, but the normal deviate corresponding to this percentage; and this is the figure given in the last line of Table 1. The value tends to

* In Table 1 of Fisher and Yates the probability given is that the value shall be *outside* the given deviation, so the value used here is $1 - P$.

TABLE 2.—*Diameters of circles within which the shown percentage of all trappings occurred, and hence within which there was the same percentage probability of being trapped. Rattus jalorensis is shown for the Pylon area only*

TRAPPINGS = PROBABILITY, %	DIAMETER OF CIRCLE IN METERS FOR					
	R. jalorensis	*R. argentiventer*	*R. exulans*	*R. müller*	*R. rajah*	*R. whiteheadi*
50	67	51	50	80	55	91
80	129	101	98	152	105	175
90	166	131	126	195	136	226
95	197	155	149	232	161	269
99	275	218	210	301	211	330

infinity as the probability tends to unity, and the scale is shown only to 2.58 corresponding to a probability of 99 per cent. The scale of percentages is also shown, and across the diagram is drawn the line corresponding to unit deviation (a probability of 68.26%). From these diagrams the diameters corresponding to probabilities of 50, 80, 90, 95 and 99 per cent are shown for each of the six species in Table 2. With this table we may return to the concept of the "home range," suitably modified, by defining, not the whole range (with its implication that the rat is confined to those limits), but that range within which the rat spends a suitable fraction of its time.

Since the probabilities are distributed normally, the most convenient measure to use is the standard deviation of this normal distribution. We may therefore define a "standard diameter" as the square root of the mean square of all diameters. This statistic will have the advantage of being least affected by random fluctuations. It defines, by implication, a "standard range," the circle of standard diameter, which will contain 68.26 per cent of all trappings.

Two ways of estimating the standard diameter are available: (1) To calculate the square root of the mean square of all measured diameters; (2) To plot the normal deviates of the frequency against the observed diameters (as in Figs. 7–9), draw the line of best fit, and see where it cuts the abscissa of unit deviate.

It will be observed from these figures that the lines of best fit pass near, but do not necessarily pass exactly through, the origin, although in theory they should do so. In the figures the line drawn is in fact the line *through the origin* which best fits the points. This line cuts the line of best fit near to the abscissa of unit deviate, so that discrepancies are least at this point. If an attempt is made to extrapolate to large ranges (e.g., 99.99%) then these differences would become considerable.

Standard diameters.—Estimates of the standard diameter for the rats shown in the three figures, and also for *Rattus sabanus*, are summarized in Table 3, and are best considered species by species. No sexual differences were observed, and the sexes were present in roughly equal numbers. The areas in which these experiments were carried out are discussed by Harrison (1957).

Rattus mülleri (Fig. 7). That this estimate is a reasonably good one is shown in Fig. 6 where the curve based on this estimate is fitted to a set of observations based on only part of the observations. The experimental area covered the whole of a valley floor and extended beyond the range of this species so that the ranges can be considered fairly representative.

Rattus sabanus (not figured). This estimate is unsatisfactory. It is based on far too few observations, and the ranges of the rats were in fact not properly covered by the experimental area. This rat lives on the hill slopes, and all of those marked were in areas fringing the experimental area.

Rattus rajah (Fig. 7). The results for the two forms, *pellax* and *surifer*, have been charted separately and give very slightly different results. The differences are trifling, however, and it is unlikely that they are due to anything but chance variation. This result reinforces the view expressed elsewhere (Harrison, 1957) that these two forms are ecologically indistinguishable, and represent but color variations of the single species *Rattus rajah*. Only one line is drawn in Fig. 7 to represent the composite species.

Rattus whiteheadi (Fig. 7). It is surprising that this rat, which is small and comparable in size to *R. exulans*, in fact has the largest range of all. This species is one of the few Malayan forest rats which can maintain itself in scrub and secondary forest.

Rattus argentiventer (Fig. 8). The result is again surprising in that the ranges of this rat and of the much smaller *R. exulans*, both of which inhabit grassland, appear to be almost identical. The results are not wholly satisfactory since this species seems less easily trapped than most others, a fact which is reflected in

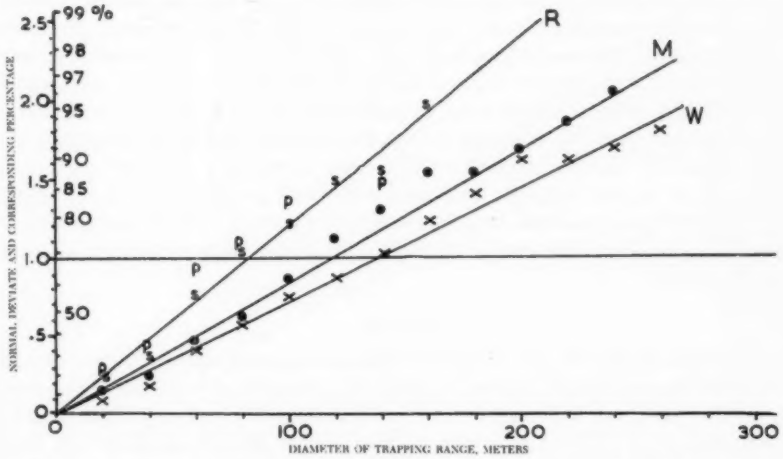

FIG. 7.—*Rattus mülleri* (*M* and dots); *R. whiteheadi* (*W* and crosses); and *R. rajah* (*R*) *surifer* (*s*) and *pellax* (*p*) all from the same area of forest. Cumulative numbers of trapping within circles of the given diameter plotted on a scale of normal deviates.

TABLE 3.—*Estimates of standard diameters from Figs. 7 to 9. For each rat are also shown the number of individuals, the minimum number of trappings included, and the total number of trappings. R. sabanus data based on an incomplete sample*

SPECIES AND HABITAT	NO. OF RATS	NO. OF TRAPPINGS		STANDARD DIA., m.
		minimum	total	
Rattus mülleri, forest	10	4	57	117
R. sabanus, forest	4	2	13	(98)
R. rajah surifer, forest	11	5	92	80
R. rajah pellax, forest	8	4	38	75
R. whiteheadi, forest	10	5	78	136
R. argentiventer, grassland	14	3	58	80
R. exulans, grassland	36	5	294	78
R. jalorensis (Pylon), grassland	27	4	175	102
R. jalorensis (Spooner Rd.), scrub	33	5	350	90
R. jalorensis (Stream), mixed grass and scrub	24	4	123	73

the rather small number of trappings recorded in Table 3, and the unusually large number trapped once only, and never retrapped, as recorded by Harrison (1956).

Rattus exulans (Fig. 8). This estimate seems to be a good one based on a large number of observations.

Rattus jalorensis (Figs. 8 and 9). Three estimates are given. In Fig. 8 is shown the line for the same area of grassland as for the last two species. In Fig. 9 this line is repeated (dotted) and compared with an area of scrub (Spooner Rd.) and an area of mixed grassland and scrub (Stream). The scrub (Spooner Rd.) gives what is probably the best figure. In the grassland the rat was largely confined to a gallery of open scrub extending through the area and the individual ranges are probably extended rather than circular, so that the diameters are overestimated. The comparatively small range in the area of mixed vegetation (Stream) is of great interest. This rat is associated particularly with the edges of woodland and grassland, and the mixed vegetation of such an area probably provides very favorable conditions which allow the rat to support itself in a smaller area.

HOMING

If the area of the 100 per cent probability zone is justifiably to be regarded as infinite, then occasional trappings should be recorded at very great distances from the center of distribution. In fact, although different experiments have been conducted within a kilometer of one another, no rat marked in one area has been recorded in another. A moment's consideration, however, will show that such a trapping would be exceedingly unlikely to occur. The probability of any trapping outside a radius of 300 m. is, for all these rats, of the order of

one in a thousand million, so that the possibility or an occurrence within a limited area at over three times that range can safely be discounted.

It was, therefore, noted with great interest that when, in another experiment, an attempt was made to increase the local density of a population by releasing rats brought from another area about a kilometer away, the rats did not remain in the new area but quickly found their way back to the original area.

This phenomenon has been investigated so far with rats of only one species, *Rattus jalorensis*. The following two experiments, called by the name of the locality in which they were carried out, are informative:

West Folly.—Rats were trapped and retrapped regularly in an area of scrub and grassland at the bottom of a small valley. Rats which had been marked and retrapped were released at varying distances up the valley, and also in the next valley, which was about 1,500 m. away and separated by an irregular scrub-covered ridge of some 50 or 60 m. elevation.

Table 4 shows the number of recoveries of rats released at these distances, each rat being counted only at the first such experience. Trapping in another similar area showed a probability of 75 per cent that any rat marked and released would be trapped again. The rats released 500 m. from the trapping area, therefore, showed no perceptible loss. Thereafter there was a drop in recovery rate with increase of distance, although the figures are too few to indicate the exact relationship.

It was necessary to consider only rats released away from home for the first

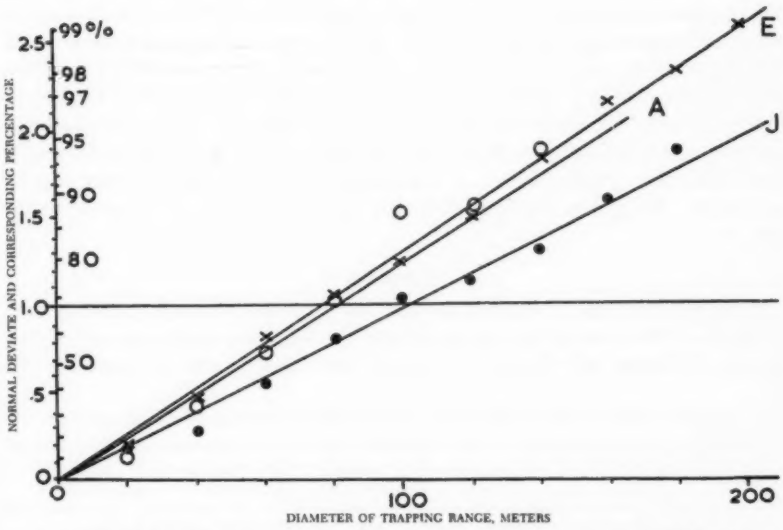

FIG. 8.—*Rattus argentiventer* (*A* and circles); *R. exulans* (*E* and crosses); and *R. jalorensis* (*J* and dots) all from the same area of grassland in the "Pylon" experiment.

TABLE 4.—*West Folly experiment. Recoveries of R. jalorensis released at varying distances from the usual area of capture*

DISTANCE, m.	NO. OF RATS RELEASED	NO. OF RECOVERIES	RECOVERY RATE, %
500	6	5	83
800	13	5	38
1,000	30	13	43
1,500 (next valley)	58	7	12

time, to avoid the danger of their learning the route home. That there is such a danger is shown by the fact that seven recoveries (45%) were made from sixteen releases made at 1,500 m. with rats which had previously found their way over that particular distance.

A few tests were made with rats of other species, and recoveries were recorded from 800 m. with *R. rattus diardi* and from 1,000 m. with *R. exulans*.

Spooner Road.—The basic area in this experiment was a region of scrub largely enclosed by the ornamental "Lake Gardens" and neighboring houses and gardens, with a low house density and many old hedgerows and areas of scrub. Rats were released at varying distances from the trapping area; the results are shown in Table 5.

Here clearly is a very different story. Of the eight rats released at less than 500 m., seven were recovered; the number expected would be six, so the agreement with expectation is good. Of the twelve rats released between 600 and 900 m., however, only one was recovered, whereas at the rate found for West Folly five or probably more would have been expected. The difference in the two areas was that, while the West Folly experiment was carried out in fairly uniform scrub, the Spooner Road area was surrounded by minor roads, and to get distances as great as 800 m. it was necessary to cross roads bearing regular car traffic. It appears very probable that these roads proved a barrier to the rats.

DISCUSSION

It should, perhaps, be emphasized that the estimates of range made here are estimates of the average for one particular species in one particular set of conditions. Different individuals undoubtedly will differ in size of range, and the

TABLE 5.—*Spooner Road experiment. As for Table 4, distances of release grouped*

DISTANCE, m.	NO. OF RATS	NO. OF RELEASES	NO. OF RECOVERIES	RECOVERY RATE, %
300–500	7	8	7	88
600–900	12	12	1	8

average sizes will differ in different kinds of vegetation. What was needed, however, was a method of comparing the ranges of different species, rather than the individual ranges of different members of the same species.

The most penetrating criticism of the value of estimates of range derived from mark-recapture experiments is based upon the undoubted fact that rats become accustomed to being trapped. In fact one gains the impression that the rats actually seek out traps in which to get caught. A dramatic example of this is given by Hayne (1950).

In the present instance it would not seem to matter whether the rats are attracted to traps or not, so long as their behavior toward the trap is constant. In experiments which involve the laying of a complete network of traps, an attraction will mean that a rat is more likely to enter a trap nearer the center of its range, and correspondingly less likely to enter a distant one. In these experiments, however, a complete network was not used. The grid was for the identification of trapping points and only a small number of traps were laid at any one time. The bait (sweet potato) has no marked odor, so it is exceedingly unlikely that any attraction was offered. The chance of trapping must be directly related to the chance of the accidental finding of the trap, which must be related to the chance of the occurrence of the rat in that part of its range.

The curve of normal error appears to give a very good fit to the observed results. It is of interest to note that the probability of occurrence is simply related to the distance of the point from the center of activity and not, as might reasonably be expected, to the area of the circle enclosed. We may perhaps in-

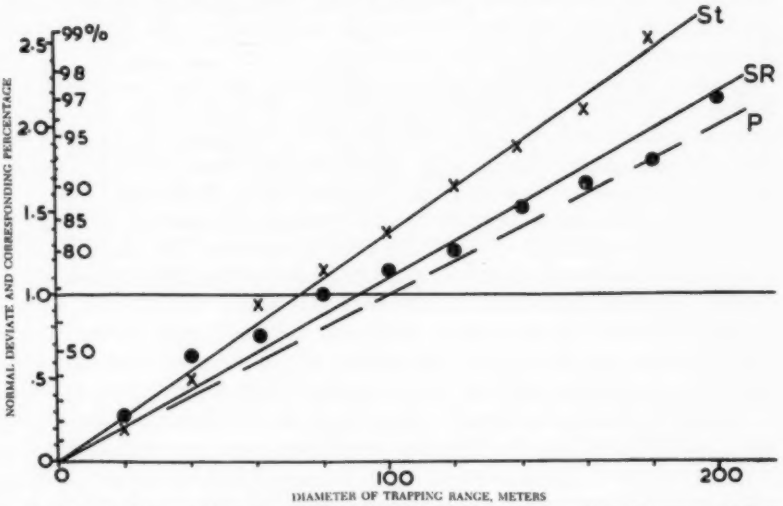

FIG. 9.—*R. jalorensis* from three different habitats: uniform scrub in "Spooner Rd." experiment (*S.R.* and dots); mixed grass and scrub, "Stream" experiments (*St* and crosses); and grassland, "Pylon" experiment, from Fig. 8 (*P* and broken line).

terpret this as suggesting that the range should be looked upon not as a continuous area but as a network of paths.

Although, mathematically, the most satisfactory estimate of the range is the standard range, derived from the variance of the distribution of the trapping points, and although this gives an adequate measure for comparative studies, it is not necessarily the most useful estimate for population studies. The rat spends 68.26 per cent of its time within this area, but that is not a very convenient figure. What is usually needed is an estimate of the area within which, effectively, all its time is spent. The theory of this method of calculation makes such an area infinite, but we can arrive at a more useful figure. Thus, from the table of normal deviates, we can see that the rat would spend 99 per cent of its time within a diameter of 2.58 standard diameters, 99.9 per cent within 3.29, 99.99 per cent within 3.89, and 99.999 per cent within 4.42 diameters. What does such a figure as 99.999 per cent of its time amount to?

Estimates of the mean length of life of these rats have been made elsewhere (Harrison, 1956). They range from 3.2 months for *Rattus exulans* to 7.8 for some populations of *R. jalorensis*; i.e., from about 100 to over 200 days. In a country of uniform tropical climate, such as Malaya, the day has about 12 hours or over 40,000 seconds of darkness, so that the mean active life of the rat may be considered as between four and ten million seconds. For such a life, 99.999 per cent of its time means all but about a minute; 99.99 per cent means all but ten minutes; 99.9 per cent means all but an hour and a half; 99 per cent means all but one or two days. A convenient estimate is that 99.95 per cent of its time, all but about an hour, is spent within a diameter of 3.5 standard diameters. For practical purposes we may therefore take the whole range as having a diameter of three and one-half times the standard range.

Homing.—The results of the test on homing ability show that the rats can find their way home from points very far outside the area in which they may reasonably be expected to be trapped. Such results are sometimes advanced as evidence that the animals possess some special directive sense, but in the present instance the results are explicable on the known habits of the rats.

Rattus jalorensis has a range of standard diameter of about 90 m. (more or less, according to habitat). On the calculation given above, therefore, its whole range can be taken as about 315 m. in diameter, and if the rat finds itself within this range it can be assumed as able to find its way home.

If the rat is now released 1,500 m. away from this circle, what are the chances that by random searching it can find its home again? First we must have some rough idea of whether 1,500 m. is a reasonable distance for the rat to travel. Watching rats which are calm after release suggests that they move along fairly slowly, exploring as they go. My estimates of their speed vary widely but they are of the order of some 10 m. a minute. At this speed a rat could cover 1,500 m. in 2½ hours if it traveled in a straight line or certainly within, say, ten hours if it meandered. It is, therefore, quite reasonable to expect the rat to have a fair chance of finding its own home within a single night.

What, however, are the chances of finding a circle of 315 m. diameter at a range of 1,500 m.? Since the search is assumed to be random, the rat may be expected to approach the home circle from any direction, and the important dimension is not the angle subtended by the home range at the point of release (as might be expected) but the circumference of the range compared with the circumference of the circle at that distance from the point of release. The probability of its discovery is, therefore, $315\pi/1{,}500\pi = 0.21$.

Our estimate is that a rat released at a range of 1,500 m. has a 21 per cent chance of finding its home range. Since the probability of the recapture of a rat is about 75 per cent, the probability that a rat, released at 1,500 m., will be retrapped in its home range will be about 16 per cent. This agrees very closely with the 12 per cent trapping rate actually observed (Table 4).

The results obtained bear comparison with those reported by Murie and Murie (1931, 1932) for *Peromyscus*. They obtained 94 per cent recovery from up to 350 yards, 82 per cent at 500–700, 45 per cent at 900–1300, 14 per cent at 1800 (a mile) and zero recovery at 7,000 yards (4 miles). The latter figure is suspect because the mice were released into an area which had been heavily trapped, and it was later found that many of these mice were recovered near the point of release. This observation, coupled with my own observation that rats, released into a new area in an attempt to thicken the population, conspicuously did not remain there, suggests that the motive for the tendency to find their way home is a search for suitable quarters. If the animals are released into an inhabited area all suitable quarters are already occupied, and the random wandering, assumed above, is forced upon them.

The fact that the rats in the Spooner Road experiment did not return, even though released within much smaller distances, suggests that the roadways, which were macadamized and bore frequent car traffic, were an effective barrier for this rat. A similar phenomenon was observed by Lawley (1957) with feral *Rattus rattus diardi* in Singapore. *R. jalorensis* does not appear to occur on the island of Singapore, and its niche of scrub is filled by *R. r. diardi*, which in other parts of Malaya is strictly a house rat. Lawley, in investigating an island of mite-typhus infection, found that rats in the infected area were heavily infested with the vector mites (*Trombicula deliensis*) whereas those immediately across a minor road bore no mites at all, showing that the populations did not mingle.

SUMMARY

In connection with work on the vector of mite-typhus, estimates of the range of movement have been made of the following Malayan rats: *Rattus jalorensis, R. argentiventer, R. exulans, R. mülleri, R. sabanus, R. rajah* (including *pellax* and *surifer*) and *R. whiteheadi.*

Rats were trapped, marked by toe-clipping, released and retrapped in a number of sample areas. Each area was marked out, usually in a grid at 20-meter intervals, and traps were placed at different points in rotation. In this way it

was hoped to sample the actual trapping rate of individual rats at that point, unaffected by intervening traps.

The results have been expressed by assembling, for each rat, the number of trappings within circles of successively smaller diameters, and plotting these numbers against the diameter. The empirical curve obtained approximates the cumulative frequency curve derived from a normal distribution, and by transforming coordinates from frequencies to normal deviates a straight-line relationship is obtained.

The best estimate of this distribution is considered to be the *standard diameter* obtained from the graph where the line cuts the abscissa for unit deviation, equal to twice the root mean square of all distances from the center of the range. The rat would be expected to spend about 68 per cent of its time within a circle of this diameter and effectively all of its time within a circle of 3½ times this diameter.

Some experiments on the homing ability of *Rattus jalorensis* are described. Rats released at varying distances up to 1,500 meters found their way home with successively reduced frequency. It is considered that this result is fully explicable by random searchings on the part of the released rat.

LITERATURE CITED

Audy, J. R. and J. L. Harrison. 1954. Collections made in Malaya by the Colonial Office Scrub Typhus Research Unit. Studies from the Institute for Medical Research, Malaya, 26: 1–22.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. Jour. Mamm., 24: 346–352.

Fisher, R. A. and F. Yates. 1943. Statistical tables for biological, agricultural and medical research. London. Oliver and Boyd.

Harrison, J. L. 1956. Survival rates of Malayan rats. Bull. Raffles Mus., Singapore, No. 27: 5–26.

———. 1957. Habitats of some Malayan rats. Proc. Zool. Soc. London, 128: in press.

——— and R. Traub. 1950. Rodents and insectivores from Selangor, Malaya. Jour. Mamm., 31: 337–346.

Hayne, D. W. 1949. Calculation of size of home range. Jour. Mamm., 30: 1–18.

———. 1950. Apparent home range of *Microtus* in relation to distance between traps. Jour. Mamm., 31: 36–39.

Hediger, H. 1950. Wild animals in captivity. London. Butterworth Publ.

I.M.R. 1952. Colonial Office Scrub Typhus Unit—Mammals. Annual Report, Inst. for Med. Res., Malaya, for 1951: 48–50.

Lawley, B. J. 1957. The discovery, investigation and control of scrub typhus in Singapore. Trans. Roy. Soc. Trop. Med. & Hyg., 51: 56–61.

Murie, O. J. and A. Murie. 1931. Travels of *Peromyscus*. Jour. Mamm., 12: 200–209.

———. 1932. Further notes on travels of *Peromyscus* Jour. Mamm., 13: 78–79.

Stickel, L. F. 1954. A comparison of certain methods of measuring ranges of small mammals. Jour. Mamm., 35: 1–15.

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SURVIVAL AND HOME RANGE IN THE NELSON ANTELOPE GROUND SQUIRREL

By Albert C. Hawbecker

As a part of a life history study on the Nelson antelope ground squirrel, *Ammospermophilus nelsoni*, observations on age, home range and dispersal were started in 1947 and continued until approximately June, 1956. The area live-trapped is 65 miles west of Fresno, California, the home base, and located where rainy weather makes the road impassable. Most time was available during the summer when heat made live-trapping hazardous for the squirrels. During most of the other nine months only week ends were available for work. This resulted in gaps in the data, but sufficient material is available to cover the points discussed.

The field work, which includes this study, was supported in its later stages by U.S. Public Health Service Grant E-723. Plants have been identified by Dr. C. H. Quibell of Fresno State College; the drawings are the work of Mr. George C. Jensen of San Francisco, California.

Area description.—The area trapped (Fig. 1, Plate I) is located 6 miles east of Panoche, San Benito County, California (Panoche Quadrangle, edition of 1913, reprinted 1924, U.S.G.S.) at an elevation of approximately 1200 feet. This would fall within the "Valley Grassland" vegetation type of Munz and Keck (1949), but more exactly is a variant of this, containing such plants as joint-fir (*Ephedra californica*), California juniper (*Juniperus californicus*) and snakeweed (*Gutierrezia californica*). Perennial poa (*Poa scabrella*) and the annuals red brome (*Bromus rubens*) and red-stemmed filaree (*Erodium cicutarium*) make up the bulk of the herbaceous vegetation.

Rainfall averages around 5 inches, but may run up to 10 inches. The area is a desert in

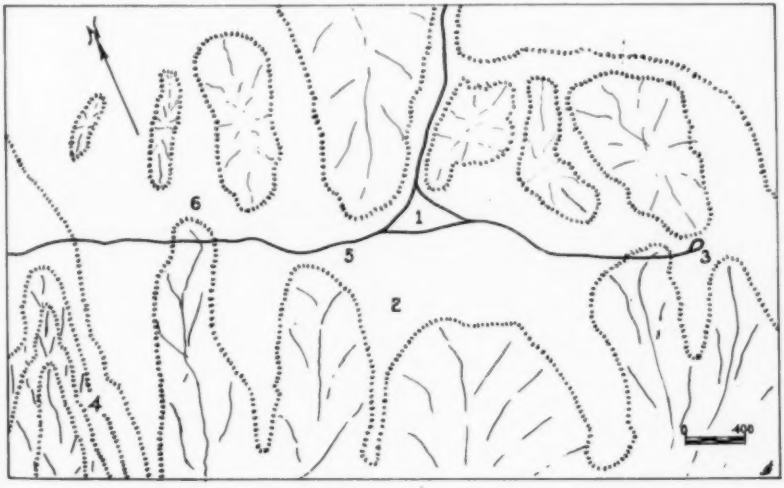

Fig. 1.—Map of study area. Numbers correspond to those on succeeding figures.

character, both in plant constituents and animal species. A more exact description of the area, and the relationships of the other animals inhabiting it, is to be found in earlier studies (Hawbecker, 1951, 1953). The area pictured shows steep hills to the south and low hills to the north. Hills and deep canyons are immediately behind the camera, making the low northwestern end of the plot the only place that might normally be used as a pathway in and out. This is assumed because this species is seldom found in steep, dissected and densely shrubby country. This low, northwestern area is used regularly to trap squirrels for other purposes, as well as to check on emigrations, and so far no marked squirrel has been found out of the study area.

Methods.—This squirrel will enter any trap into which it can fit, and twice it has been taken in small can traps into which it had to squeeze. In this respect, it differs from the California ground squirrel, *Citellus beecheyi*, as described by Horn and Fitch (1946), which must be able to see out of a trap in all directions, or it will not enter. The best results were obtained with Havahart live trap No. 1, or with the smallest of the National Live Trap Company's folding traps. It was found necessary to use a "hair-trigger" type of set, and even then traps were often picked clean of bait without being sprung. This tendency is not due to wariness of the trap on the part of the squirrel, as the squirrel is certainly not trap-shy. The animal just moves about in a careful manner all of the time. Ten to 12 traps were used in this work, and moved from place to place. No grid pattern was used because, early in the work, it was found that unless a squirrel was seen at a particular place, there was little use in setting a trap there. Traps were often placed at likely spots but usually remained empty. Traps were set where squirrels were seen to go down and then, if one was caught, the position was recorded. Trapping was done when time was available. No attempt was made to catch all of the squirrels on the area at any one time.

Usually the squirrel approaches the trap with some caution. All bait around the trap is picked up, and even some tunneling under the trap may be started. If the trap is accidentally sprung, then tunneling may be so extensive as to dislodge and make available all of the bait. In almost every instance, however, the trap is entered—the quickest path to the food is taken. Rolled oats was found to be the best bait and was readily accepted at any time of the year. This is particularly interesting during the spring when there is an abundance of green ma-

PLATE I

The study area. Picture taken looking west from Point 3, Fig. 1.

terial, which seems to be important during the period of lactation. It was found in an earlier study (Hawbecker, 1947) that a certain amount of seed material is always present in the stomach of the squirrel no matter what the availability of other food types. The high protein content in seeds of any type—native seed or rolled oats—may answer a need. Less understandable is the ready entrance of traps during the early summer when there is a concentration of dry seeds on the ground. Protein content of these must be high and they are a much more familiar sight than the rolled oats. Forty-nine squirrels were taken in three days in June, 1953, when there was a great deal of seed material on the ground.

The usual toe-removal method was used in marking. No serious shock seemed to result, as in one instance the newly marked squirrel re-entered the trap in 40 minutes, another in one hour, and several within two hours. Traps are usually re-approached, and scattered bait picked up, within five to ten minutes, if the time falls near the middle of the feeding period. There is little evidence of permanent disability, as marked squirrels show up consistently for months and years. It must be pointed out, however, that most marked squirrels are not retaken the following year. There is the possibility that the lack of toes may make the squirrel a little less agile, which might be fatal during the critical months. In this desert country, where food may be scarce through the late summer, fall and early winter, this may be an important consideration. The number that are able to survive suggest, however, that the great loss is due to natural attrition.

Response to temperature.—Later in the study, when summer trapping was started, the squirrel's response to high temperatures was quickly demonstrated. It was apparent in earlier work (Hawbecker, 1953) that the squirrel moves about very little in the cold, but even less in the heat. Here it was found that when exposed in the hot sun to a temperature of 88–90°F. (thermometer in the shade), the squirrels die. When exposed, their actions soon become frenzied and a frothing at the mouth occurs which may be a type of perspiration. Convulsions take place followed by a rapid slowing down of activity, and death ensues. Once this cycle has been started, removal to shade and cooling the body will not save the animal. Three instances of this occurred on June 26, 1953, when traps were left out too late in the day. Shade temperature was exactly 90°F., but open-ground temperature was 114°F. and relative humidity was 6 per cent. Temperatures 24 inches underground, at this time, were 10–12 degrees less than shade temperatures, and the relative humidity was 33 per cent. Other instances of death under the same conditions have been noted. An occasional squirrel does venture out in the hot sun but, observably, for only a short time. A rather dramatic account of the effect of heat on captive squirrels released in the sun is discussed in an earlier account (Hawbecker, 1947). There is very little activity during the heat of the day. It was suggested earlier (Hawbecker, 1947) that the adults are less active during the summer; in fact that they might aestivate. In this study, where marked adult squirrels could be followed throughout the year, there was no evidence of either aestivation or hibernation. So few adults are taken in comparison with numerous young that dormancy seems indicated, but such is not the case.

The cold does not bother the squirrels as much. In several instances adult squirrels were left out all night without food on nights below 32°F. and they were still very active in the morning. In one instance, trapped squirrels were left out in a two-hour soaking rain, but besides being very wet there were no ill effects. Very young squirrels, known to be less than three months old, died on a cool but not cold night in May when confined without food. Young at this stage weigh about 40 grams and lack fat, while adults weigh 4–5 times as much and possess fat. Generally, squirrels are not out in temperatures of less than 50° F. unless feeding during a prolonged cold spell.

Survival.—Survival in this species is limited largely to the year in which the individual is taken. Two hundred and forty individuals were taken between November, 1947 and December, 1954. Of these, 193 were not taken again later than nine months after their first capture. This indicates that 80 per cent of the animals do not survive from one year to the

TABLE 1.—*Ages reached by those squirrels that lived longer than one year. In all cases the squirrels appeared mature when marked; only those marked early in the study are included*

NO.	DATE MARKED	DATE LAST TAKEN	MINIMUM AGE
3♀	11-11-47	11-12-48	1 yr.
10♂	12-13-47	6-25-53	5 yr. 6 mo.
17♂	12-13-47	1-22-50	2 yr. 1 mo.
22♂	1- 9-48	8- 3-53	5 yr. 7 mo.
30♂	11-12-48	1-21-50	1 yr. 2 mo.
40♀	11-19-49	7- 2-55	5 yr. 8 mo.
42♀	1-22-50	3-27-54	4 yr. 2 mo.
51♀	1-22-50	6-17-54	4 yr. 5 mo.
51b♂	2-20-54	6-11-55	1 yr. 4 mo.
54♀	2-18-50	5-11-52	2 yr. 2 mo.
55♀	11-12-51	2- 8-56	4 yr. 3 mo.
56♀	11-12-51	3-27-54	2 yr. 4 mo.

next. In a specific case, of 49 squirrels marked from June 16–18, 1953, only 15, or slightly more than 30 per cent, were retaken another year. Most of these were young of the year. A number of other examples indicate this; in almost all, the critical period seems to be the summer period, i.e., they were trapped only in the late spring or early summer, but by fall or winter had disappeared. Survival through the summer period is clearly critical with squirrels of all ages, not seemingly more serious with the young. Squirrels that had survived one summer and were marked during the winter appeared to run the same chance of survival as young. Of 55 such marked during the winters of 1947-1951, only 10 were picked up after the following summer. Several repeats may be made in the winter, but all track is lost during, or after, the following summer. There is further evidence of this in that 29 animals were caught after one year, but only 12 of these after two years, which indicates a mortality of 60 per cent in adult, well-established squirrels.

This critical summer period may be coupled with a winter period nearly as critical. An earlier paper (Hawbecker, 1953) demonstrated how foraging reactions are related to both heat and cold. The heat of the summer forces the squirrels to forage early in the morning and late in the evening, and although there may be plenty of food in the form of seeds, this is also the foraging time of many of the predators on the area. During the winter there may again be sufficient food present but cold, foggy or windy days cause much difficulty in feeding. Each condition has its restrictions, but the greatest mortality occurs during the summer period, or at least before the green growth starts the following winter.

There is evidence that a great amount of food may aid in survival. This, of course, reduces the amount of time necessary to get sufficient food, whether winter or summer. The winter season of 1951-52 was wet and warm, a combination that results in a heavy growth the following spring. Filaree, normally 2–4 inches high with one of two flowering heads, was 12–14 inches high with numerous flowers and resulting seeds. Other seed-producing plants, such as red brome and pepper-grass (*Lepidium nitidum*), produced accordingly. Trapping in the fall of 1952 and early in 1953 showed that where a take of 8 squirrels per trapping day had been usual, this year it was possible to get 18 per day. There had been a build-up in the population. In June, 1953, after the young had emerged and become large enough for the traps to hold them, 70 squirrels were trapped—far more, by comparison, than at any time before or since. Forty-nine of these were trapped in one three-day period. More significantly, however, only 20 of these were known to be present up to February, 1954. This would mean about a 70 per cent loss by the next breeding season. Similar projects here, working with

such species as the Tulare kangaroo rat (*Dipodomys heermanni tularensis*) and the giant kangaroo rat (*Dipodomys ingens*), showed a similar response to the new conditions. The following seasons did not produce such growth, and in 1954 and 1955 conditions and survival of young were back to the pre-1952 level.

Age and sex ratio.—Fifty-five squirrels have been trapped and marked that might have been recovered up to at least five years later, but only three have lasted that long. Two kept in captivity were taken as young in September, 1946, and were found unaccountably dead during the fall of 1952. Table 1 gives an idea of life spans, in some of which cases the squirrels may still be alive. The five-year-olds have not been taken for at least a year, however. This shows that although five to six years may be the maximum age, very few live that long. There is no difference in survival between the sexes.

If the system employed in this study gives a true picture, mortality is very high. Two hundred and forty animals were marked up to December, 1954, and of these 193 were not taken after the same season in which they were marked. Twenty-nine were taken one year after marking, none three years after marking, three after four years and three after five years or more. Reasons for this mortality have already been discussed.

Of a total of 272 squirrels marked, 116 (approximately 43 per cent) were females. This figure is questionable, however, as trapping records show that if both sexes were taken at one site, almost invariably the male was taken first. This has also been the experience of Harold LeRoy Wilson, of the California Department of Agriculture, who has trapped many of these squirrels. This may result in fewer females being caught or in their actually being driven away from the trap. I believe that the sex ratio is even.

Age classes are fixed. Young are nearly all born in March and are first seen above ground in, or near, the first week in April. This is the only breeding season and it coincides with

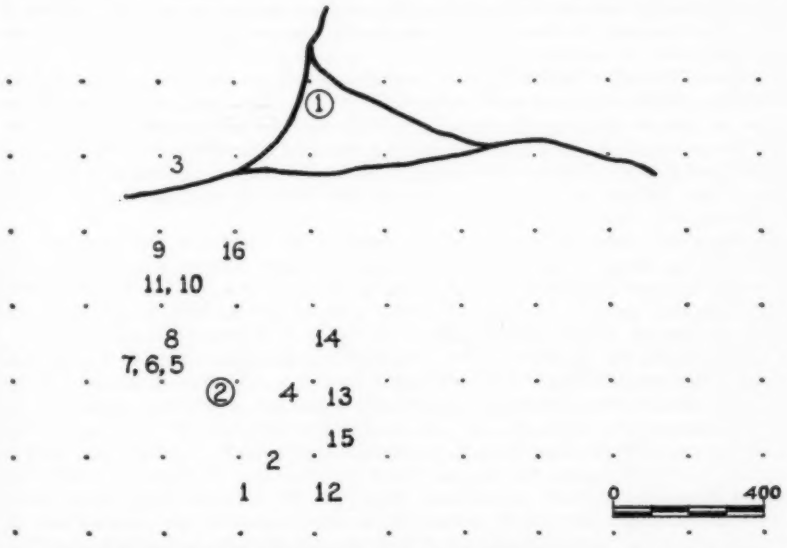

FIG. 2.—Movements by dates of No. 93. Circled numbers correspond to those on Fig. 1. 1, 2—June 17, 1953; 3, 4—June 24, 1953; 5–8—July 2–4, 1953; 9—Nov. 7, 1953; 10, 11—Dec. 23, 1953; 12—Feb. 20, 1954; 13—March 27, 1954; 14—May 22, 1954; 15—June 16, 1954; 16—Sept. 8, 1954.

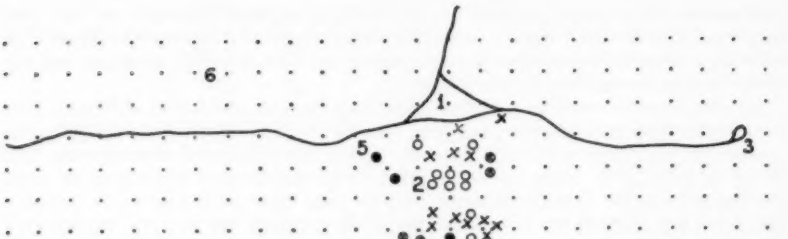

FIG. 3.—Movements and trapping sites of males.

the one period of the year when green vegetation is present. Young are recognized by pelage, size and sexual development. By the following year it is impossible to tell the age groups apart, unless they are marked.

Home range.—This is interpreted in many different ways by different workers (Hayne, 1949); here it is considered as that area enclosed by points of capture. After trapping and merely observing these animals for the last 15 years, this seems to be as good a method as any. More important, however, are the areas in that range where trapping seems to indicate that activity is centered.

In an earlier study (Hawbecker, 1947) a single squirrel, sex unknown, was watched for 3½ hours. During this time it made a circuit of 1,250 feet. From one end of this plot to the other was actually 400 feet. The spot to which the squirrel finally returned suggested that this was just one radius of a range that could be assumed to be 800 feet in diameter, and about 11 acres in all. There is evidence that the squirrel covers but one half of its range per day, or less. Squirrels are seldom trapped in the same place the following day, but usually are the day after that.

By the end of 1954, 240 squirrels were trapped. Of these, 117 were taken but once, 58 twice, 29 three times, 17 four times, 4 five times, 4 six times, 3 seven times, 1 each, eight, nine and ten times, 2 eleven times, and 1 each twelve, thirteen and sixteen times. Some of the retakes were spread over several years while in other cases only from a few days to one year were covered. Length of time, however, seemed to be of little significance.

An adult male, No. 93, will be discussed in detail and the others compared with it. Reference will be made to Figs. 1–4 for orientation. Captures of No. 93 were spread over one complete year but were contained in an area of 600 by 800 feet, or roughly 11 acres (Fig. 2). The first two captures, on the same day, were at about the same place. The third capture, one week later, was 600 feet from the first, and then the fourth, on the same day, was back at the original site. It appears that this spot was a preferred area, or burrow, and when disturbed the squirrel returned. A week later, August 2, 1953, the squirrel was trapped about 400 feet north of this spot and all captures for the next few months were centered here. In February the center of interest was moved back near the first site and captures until June 16, 1954, were made there. The last capture, the next September, was back in the northern area. It is seen that the squirrel was always in the same general area, but shifted around in and ranged over it, somewhat. No unusual movement was noted during the breeding period.

An adult male, No. 92, first captured on the same date and at nearly the same spot as

No. 93, was recaptured nine times over a 2-year period. Several captures were at the same location as those of No. 93, but the centers of activity of the two, indicated by the numbers of times captured at a particular spot, were at least 300 feet apart. This is seen by comparing Figs. 2 and 3. The first and last captures of No. 92 were at exactly the same spot. The area of the range is approximately the same as that of No. 93. There are indications of movement within the range, but none that can be correlated with the breeding period.

No. 167, an immature male when first caught, was first taken on August 12, 1954, and has been taken twelve times in the last 2½ years. It has been taken occasionally in the centers of Nos. 92 and 93, but its main activity has been on the southern edges of the ranges of those two (Fig. 3). Its range is not unlike that of No. 93, and it also shows some evidence of shifting centers of concentration within the range. There is no evidence of unusual movement linked with immaturity or breeding season. No. 168, also an immature male at first capture, was taken first and last on the same dates as No. 167 but shows a much more restricted pattern. Its first two captures, August and November, 1953, were at exactly the same place, but from January, 1955 to February, 1956 it was taken nine times 600 feet southwest of the first point. This shows 600 feet of movement before settling down, but this amount is not significant.

There have been variations on this behavior. A male first taken in January, 1948, near Point 4 was not retaken for 5½ years, when it was caught three times from June to August, 1953, near Point 2 (Fig. 1). This would represent 2,200 feet of movement, which is unusual. All distances are measured on a straight line. An immature male was taken 2,000 feet east of the point of first capture after one year, and four years later was taken 1,800 feet back in the direction of the original capture. A third had moved 1,500 feet in one month. and a fourth 3,400 feet in three months. The greatest amount of movement recorded was by an immature male that moved 4,200 feet over six months.

Twenty-nine adult males were caught a varying number of times over one complete year. Twenty-two of these showed no movement outside the 11-acre range. Seven ranged much further. Eight adult males were recaught up to five years later and, of these, five were always recaught in the same range, but three had moved. Fourteen immature males showed no movement in one year, while four did; and three immature males picked up after the first year had not moved.

Females show much the same behavior as males. An adult, No. 56, was taken six times from November, 1951, to March, 1954, and was never found more than 300 feet from Point 1

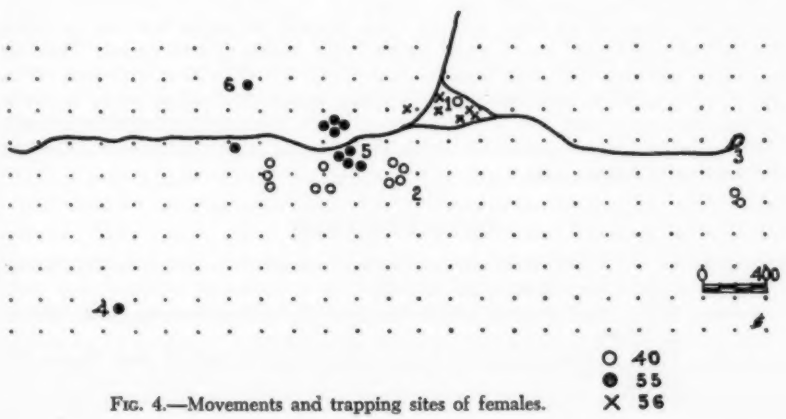

FIG. 4.—Movements and trapping sites of females.

(Fig. 1). Another female taken the same number of times, over a period of four years, was never taken outside a 400-foot radius.

There are exceptions. No. 40 was taken twice, late in 1949, at Point 3, then in June, 1953, at Point 1. In late 1953 and early 1954 its activities centered near Point 5, and then in June, 1955, it was taken four times near Point 2 (Fig. 1). Here is a long move, and then no definite center of activity, although the later captures are loosely grouped. No. 55, an adult, was first taken in November, 1951, and ten more times up to February, 1956. It was first caught at Point 4 and then, in June and August, 1953, it was caught near Point 5 (Fig. 1). On February 7, 1954, it was caught at that place and four hours later it was caught at Point 6. This represents a movement of 900 feet in four hours. On June 17, 1954, it was caught 400 feet south of that point and the next day it was back near Point 5 where it was caught three more times in the next year and a half. Another female caught over a period of four years moved 1,200 feet. Nineteen adult females were caught a varying number of times over one complete year. Only two of these showed movement beyond that expected within the normal home range. Nine were caught over several years, and of these three had moved beyond the expected range. Fifteen immature females caught within one year showed that only one had moved excessively. Four females picked up after the year period showed no movement.

It appears, then, that the great number of squirrels, sex and age notwithstanding, do not move out of an expected area. When there is movement, it cannot be correlated with sex, age or breeding season. Population pressure or changes in the food supply seem to be the only explanation at present.

Conclusions.—This squirrel is easily trapped. Rolled oats are readily accepted at any time of year.

There is a quick response to high temperature, with 90°F. (in the shade) a lethal temperature when squirrels are confined in the sun. Cold is not liked by the animal but adults move about more readily in cold than in heat. Young are killed by the cold—even when it is well above freezing.

There is no evidence of hibernation or aestivation.

Greatest mortality is during the first year, but survival the first year does not insure survival the succeeding year or years, as mortality is high in adults.

Food appears to be a major factor in survival of young of the year. If there is an abundance of food, more young survive. 1953 was a peak year after a good food year in 1952.

Maximum age in both sexes seems to be nearly 6 years. The ratio of the sexes is 1:1, or nearly so. There is just one breeding season.

The normal home range of both sexes is about 11 acres, with areas of concentration within this plot and some moving about within it. Most squirrels are caught first and last within this area, whether caught over a period of only a few months or several years. There are exceptions, however, where both sexes and both young and adults have made long moves. These moves cannot be correlated with the breeding season. The longest was by an immature male that moved 4,200 feet. The longest move by a female (an adult) was approximately 3,000 feet. These moves may be due to population pressure or changes in food supply, but this point needs further work.

LITERATURE CITED

HAWBECKER, A. C. 1947. Food and moisture requirements of the Nelson antelope ground squirrel. Jour. Mamm., 28: 115–125.

———. 1951. Small mammal relationships in an Ephedra community. Jour. Mamm., 32: 50–60.

———. 1953. Environment of the Nelson antelope ground squirrel. Jour. Mamm., 34: 324–334.

HAYNE, D. W. 1949. Calculation of size of home range. Jour. Mamm., 30: 1–18.

HORN, E. E. AND H. S. FITCH. 1946. Trapping the California ground squirrel. Jour. Mamm., 27: 220–224.

MUNZ, P. A. AND D. D. KECK. 1949. California plant communities. El Aliso, 2: 87–105.

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RELATIVE EFFICIENCY OF DIFFERENT SMALL MAMMAL TRAPS

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At some time in any study of small mammal populations the investigator is faced with the problem of whether the particular kind of trap used will adequately sample the population. It is common knowledge that exclusive use of one type of trap will tend to bias the estimate of population density due to varying amounts of selectivity in obtaining a population sample, since different types of traps vary in efficiency with respect to numbers, genera and species caught. Trap size and the correlated mechanical sensitivity of the trap also are obviously selective with respect to the size of specimen taken. An apparent avoidance of certain kinds of traps by some genera and species may involve odor, the appearance of the trap to the animal, or trap placement. However, certain anthropocentric concepts are involved here which are difficult to evaluate. Painting traps or camouflaging them in various ways have been used by some to overcome any real or assumed behavior of this sort without giving much quantitative evidence of success. Successful fur-trappers apparently employ these methods with considerable success to overcome reaction of the animal to the trap. There may also be individual variation in response to traps, as suggested by Young *et al.* (1952), Tanaka (1952, 1956) and Geis (1955), which would, if present, introduce a bias with respect to numbers of particular species trapped. The behavior of individuals and species is thus an important factor to consider in sampling any small mammal population. Although bait preferences (Fitch, 1954) may play an important part in seasonal trap response, they are probably of little importance in determining success of different trap types and use of the same bait in all traps compared at the same season would tend to nullify this factor.

Cockrum (1947) found that live-trapping provided a much more reliable index of population density than did snap-trapping, but Goodnight and Koestner (1942) came to the opposite conclusion. Several investigators (Christian, 1936; Clarke, 1938; Prince, 1941; Edwards, 1952; Fowle and Edwards, 1954) have also shown that some species are not easily caught in conventional traps whereas they may be quite abundant in the habitat. These studies, plus the desirability of determining the type of trap which would provide reasonable population estimates by catching a wide variety of small mammals in maximum numbers, prompted us to make a series of somewhat similar experiments in an attempt to evaluate the relative merits of several kinds of traps. Several types of small-

and medium-sized traps were compared and the results of these comparisons are presented as further evidence of bias in sampling small mammal populations based on the kind of trap used.

The study was carried out mainly in an upland oak-pine forest located approximately 10 miles north of Pine Bluff, Jefferson County, Arkansas. The vegetative composition of the area was determined by the random pairs method (Cottam and Curtis, 1949) and the minimum-area method (Vestal, 1949). Several species of oaks and pines were dominant in the association. The principal species were as follows: southern red oak, *Quercus falcata*, 35, post oak, *Quercus stellata*, 15, white oak, *Quercus alba*, 7, loblolly pine, *pinus taeda*, 15, and yellow pine, *Pinus echinata*, 15 per cent. Other tree species present were mockernut, *Carya tomentosa*, 5, sweet gum, *Liquidambar styraciflua*, 1, and an assemblage of less abundant species with a combined total of 2 per cent.

MATERIALS AND METHODS

Traps.—The following types of small- and medium-sized mammal traps were used: Museum Special snap trap; Victor 4-way snap trap; Sherman live trap—the larger size (3 × 3 × 10 in.) which is the most efficient for small mammals (Quast and Howard, 1953) was used; Young live trap—a single-door hardware-cloth trap (4 × 4 × 15 in.) with a trigger mechanism designed by Howard (1953) which was originally used in an attempt to eliminate trap mortality during hot weather; Wisconsin-type live trap—a wooden trap (3 × 3 × 11 in.) similar to the Blair (1941) "36" trap and to one developed by Baumgartner (1940), but with an improved trigger mechanism. It was used by Young *et al.* (1950) in indoor studies on house mouse populations in Wisconsin. In field use it has proven unsatisfactory and much less efficient than other live traps on an over-all basis because of its tendency to swell in wet or damp weather causing impairment of the trigger mechanism and difficulty in removing animals from traps; Havahart live trap—this well-known trap (7 × 7 × 24 in.) was used for medium-sized mammals; Modified Evans vermin trap—a modified version used by the Michigan Department of Conservation; National live trap—double-door traps of two sizes (6 × 6 × 24 and 9 × 9 × 32 in.) were used. The larger size proved most efficient for general field use; water traps—these consisted of No. 10 food canisters (ca. 6 × 8 in.) two-thirds filled with water.

Trapping methods.—Two general approaches were used to compare trap efficiency. One consisted of using water traps surrounded on all sides by Victor 4-way snap traps, while the other involved various comparisons between different types of live traps or between live traps and snap traps.

The water traps were sunk flush with the ground in an irregular line placed about two paces apart in oak-pine forest. Prior to trapping, it was experimentally determined that when two-thirds filled these canisters would hold mammals the size of *Peromyscus* or *Blarina* although mammals the size of adult *Sigmodon* or *Oryzomys* could escape. An element of selectivity was thus introduced into this type of trapping from the start. Our results thus apply only to the smaller-sized mammals not able to escape from the water traps. Every other water trap was surrounded on four sides by 4-way Victor mouse traps baited with peanut butter and set approximately 3 inches from the lip of the can with treadle outward. Small mammals caught in these water traps would have to pass one or more of these snap traps before falling into the water trap. Some measure of the effectiveness of unguarded as compared with guarded water traps could thus be obtained.

Live traps and snap traps were compared in various ways as follows: in one case a circular acre plot was trapped for a given length of time with 150 Sherman traps. A short while later the same plot was trapped for about the same length of time with 150 Young

traps. At the end of this trapping period the plot was trapped with 150 Sherman and 150 Young traps placed side by side followed by a period of snap-trapping with 150 Museum Specials. The same trap locations were used in all three trapping periods. Another series of comparisons was made in a one-acre plot in which 150 Sherman and 150 Young traps were placed side by side in the same trap locations occupied by 150 Sherman traps during an initial trapping period. Still another series of comparisons was made using 150 Sherman, 150 Young and 150 Museum Special traps placed side by side in a circular acre plot. Several series of comparisons were also made using a group made up of a Sherman, Young and Museum Special trap placed side by side and strung out linearly, each trapping location being separated by an interval of 20 feet. The number of groups used with linear spacing ranged from 50 to 100. All traps were baited with peanut butter.

A few comparisons were made between the Evans, National and Havahart traps using various types of bait and lures or with no bait or lures. These comparisons were made in a 77-acre area in an upland oak-pine forest. A variety of commercial scents and lures were used either alone or in combination with baits such as sardines, smoked herring and shelled corn. The results were rather inconclusive and showed no good correlation between species captured and bait or lure used; consequently no details involving this comparison will be presented. About an equal effectiveness of the Evans and National traps was indicated by the trapping results and the Havahart traps appeared to be relatively ineffective by comparison.

RESULTS

Comparison of catches in randomly located water traps is presented in Table 1. Water traps guarded by baited snap traps caught almost twice as many mice in approximately the same number of trap-nights as did unguarded water traps, although the difference was not statistically significant. It would appear, however, that the additional attraction of bait in the vicinity of the water traps may have increased the probability of the animal falling into the guarded trap, if not first captured in a snap trap. If the total water trap catch is compared with the snap-trap catch, no significant deviation from expected results is evident. If the trapping pressure as indicated by the total number of trap-nights is considered, then it becomes apparent that the snap traps would be expected to catch approximately twice as many small mammals as the combined number of water traps and four times as many mice as the water traps which they surround. Compared on this basis, the combined water traps caught more than twice as many small mammals as expected and the difference was significant at the 1 per cent level ($X^2 = 10.7$). The water traps surrounded by snap traps caught about three times as many small mammals as expected with the difference being significant at the 1 per cent level ($X^2 = 12.0$).

The results clearly show that snap-trapping alone may give no reliable estimate of the population and that water traps are about equally effective. The fact that the snap traps were concentrated in 113 locations rather than in 452 separate locations obviously greatly influences the comparison. If each group of four snap traps around a water trap were considered as one trap only, it is obvious from inspection of the data that the water traps surrounded by snap traps were almost equally efficient in catching certain species.

A comparison of the relative effectiveness of Sherman and Young live traps versus Museum Special snap traps is presented in Table 2. The Sherman traps were much more effective than the Young or Museum Special traps which were about equivalent in effectiveness. Although the Wisconsin-type traps were used in some earlier studies they did not enter into this comparison because of their relative inefficiency in general field use as compared with Sherman and Young traps.

The number of trap-nights is not of great importance in comparing relative efficiency of traps where the different traps are set side by side in the same location and exposed to the same meteorological conditions since the trapping pressure and other variables would be the same in all cases. The number of trap-nights is of some importance, however, where

sequential trapping operations with different types of traps are carried out under dissimilar meteorological conditions and in some instances with traps placed in somewhat different locations.

In computing trap-nights all groups in which one or more traps were sprung by rain, birds or reptiles were eliminated from the direct comparison. Oddly enough, the Young traps caught as many reptiles (10) as did the Sherman and Museum Special traps combined (10). Reptiles captured in order of frequency were *Terrapene carolina* (9), *Agkistrodon mokasen* (4), *Cnemidophorus sexlineatus* (2), *Eumeces* sp. (2), *Sceloporus* sp. (2), and *Coluber constrictor* (1). Copperheads were captured often in other trapping studies being carried on simultaneously and were perhaps attracted by the odor of small mammals on the traps, although no evidence was obtained to show that they had entered traps after small mammals were caught.

In comparisons between Sherman, Young and Museum Special traps set side by side in identical locations, the only groups compared were those in which (1) all traps remained set, or (2) one or more traps had catches. Rain introduced a bias into the comparison which is difficult to evaluate. Snap traps were most sensitive to rain, Sherman traps least sensitive and Young traps intermediate. Usually rains would spring most of the snap traps but few live traps. Therefore, on rainy nights any evaluation of the efficiency of snap traps would be biased (unless all snap traps were sprung as was usually the case) since only the successful traps (containing specimens) and those remaining unsprung would be considered in the comparison. There would be no way to determine the number which were open at the time the specimens were caught, but later closed by rain thereby reducing the probability of additional captures. If these catches are included in the total trap-nights the ratio of catch to total will be higher than actually exists. Any over-all efficiency rating of a trap on rainy nights would then depend upon its sensitivity to rain. Thus, in order for the results to be strictly comparable, they would have to be weighted in accordance with trap sensitivity to rain. On certain grounds this might be justifiable, but from a practical standpoint would confuse the issue since the object of this and other comparisons was to select a trap which caught the largest population sample under the widest variety of conditions. Only a few of the comparisons reported here would be biased by the factor of rain as in most instances all snap traps were sprung on rainy nights thus eliminating all group comparisons for those nights.

The Sherman traps appeared to be the most generally effective type at all seasons and with most species excepting the golden mouse, *Peromyscus nuttalli*. This species was taken in snap traps with about the same frequency as in Sherman traps but it apparently did not readily enter the Young traps. Golden mice were easily trapped contrary to the experience of Goodpaster and Hoffmeister (1954). As noted by Holdenreid (1954) the small percentage of captures in Young traps may have been due to inability to set these traps regularly so as to trip with the light weight of deer mice and similar species. However, a hair-trigger set was used as much as possible with the Young traps used in this study and experimentally they were shown to trip easily with weights of 10 to 20 grams placed on the treadle. The fact that a single-door Young trap was used in this study may have affected the trap success to some extent as Holdenreid (*ibid.*) indicates that mice in his comparison study were least hesitant to enter the double-door type, but he did not compare single-door with double-door traps.

DISCUSSION

In order to get the most accurate and unbiased estimate of mammal population size it is necessary to consider many variables such as size and representativeness of the sample plot, meteorological conditions, bait, placement of traps and the numbers, spacing and kind of traps used. It is evident from many studies that mammals may be caught more often in one type of trap than another and that different types of traps used for sampling small mammal populations may give biased population estimates. In order to arrive at reasonably

accurate estimates various sizes, numbers, spacing and types of traps must be used. In most small mammal population studies it is not feasible, for various reasons, to use more than one or two types of traps. Therefore, it is of prime importance to the investigator making quantitative population studies that he use traps which have actually been proven by field trials to be relatively efficient for taking several species of mammals. If the study is concentrated on only one or two species it may be desirable to choose a trap which is selective for the species being studied.

Individual or group behavior is obviously an important factor in determining trap success. The range of daily movements, reaction to baits, and response to the trap itself are all part of an animal's behavior pattern. It is well known that individual animals may react to a live trap in such a way as to acquire either "trap-habit" or "trap-avoidance" behavior patterns. The amount of initial avoidance of traps by mammals in a given area has thus far been determined only indirectly, although marking studies have brought out the development of "trap-habit" and "trap-wariness" among individual animals (Geis, 1955; Tanaka, 1956; Young *et al.*, 1952).

On a theoretical basis, it might be assumed that different types of traps side by side in identical locations would have an equal chance of success. Also, it would be assumed that traps of different types used in identical locations would give comparable population estimates if used sequentially in the same sample plots, provided that no undue mortality was caused by trapping and that weather conditions were comparable. These assumptions are based, of course, on the obviously false premise that different types of traps are equally effective in catching mammals.

Our results show clearly that some kinds of traps are more effective than others. They do not give any idea of the number of animals which did not encounter or may have "avoided" all of the different types of traps used. Fowle and Edwards (1954), in an attempt to determine bait preference, found that unbaited traps in the vicinity of baited ones took more animals than some of the baited traps. They point out that baited traps

TABLE 1.—*Comparison of catch in unguarded water traps and in water traps guarded by snap traps; all trapping done in oak-pine forest; peanut butter used as bait*

TRAPPING PERIOD AND COVER TYPE	SPECIES	UNGUARDED			WATER TRAPS GUARDED BY SNAP TRAPS					
		Water traps (unbaited)			Water traps (unbaited)			Snap traps (baited)		
		No. traps	Trap-nights	Catch	No. traps	Trap-nights	Catch	No. traps	Trap-nights	Catch
Jan. 4–Feb. 4, 1954; 23 nights	*Peromyscus leucopus*	40	920	2	40	920	5	160	3680	1
	Peromyscus nuttalli			–			–			1
	Peromyscus maniculatus			–			1			
Feb. 18–Mar. 18, 1954; 26 nights	*Peromyscus leucopus*	44	1144	1	44	1144	–	176	4576	4
	Peromyscus nuttalli			–			1			2
	Blarina brevicauda			2			1			1
May 3–May 20, 1955; 19 nights	*Peromyscus leucopus*	30	570	–	29	551	–	116	2204	2
	*Sylvilagus floridanus**			–			1			
	Totals	114	2634	5	113	2615	9	452	10460	11

* Juvenile, small enough to be taken in snap trap.

TABLE 2.—*Comparative efficiency of Sherman, Young and Museum Special traps uniformity baited with peanut butter*

TRAPPING PERIOD	DISPOSITION OF TRAPS	COVER TYPE	SPECIES	SHERMAN		YOUNG		MUSEUM SPECIAL	
				Trap-nights	Catch*	Trap-nights	Catch*	Trap-nights	Catch
Oct. 20–22, 1954; 3 nights	Evenly spaced through 1–acre plot	Oak-pine forest	*Peromyscus leucopus*	450	5(3)	N.O.		N.O.	
Nov. 2–4, 1954; 3 nights	Same locations as above	Oak-pine forest	*Peromyscus leucopus* *Peromyscus nuttalli* *Oryzomys palustris*	N.O.		450	1(1) 1 1	N.O.	
Nov. 11–16, 1954; 6 nights	Side by side, same locations as above	Oak-pine forest	*Peromyscus leucopus* *Peromyscus nuttalli* *Glaucomys volans*	898	6(7) 3 1	898	—	N.O.	
Nov. 17–19, 1954; 3 nights	Same locations as above	Oak-pine forest	*Peromyscus leucopus*	N.O.		N.O.		450	1
Dec. 8–10, 1954; 3 nights	In line at approx. 20 ft. intervals	Mature floodplain forest, some pine	*Peromyscus leucopus*	450	6(5)	N.O.		N.O.	
Dec. 15–19, 1954; 5 nights	Side by side, same locations as above	Mature floodplain forest, some pine	*Peromyscus leucopus* *Peromyscus gossypinus*	750	1 —	750	(1) 1	N.O.	
Jan. 5–12, 1955; 5 nights	Side by side, evenly spaced through 1–acre plot	Oak-pine forest	*Peromyscus leucopus* *Peromyscus nuttalli* *Mus musculus* *Glaucomys volans*	900	2(4) 4 (1) 3	1 900	1(2) 1	N.O.	
Jan. 12–13, 1955; 2 nights	Same locations as above	Oak-pine forest	*Peromyscus nuttalli*	N.O.		N.O.		300	5
Feb. 2–15	Side by side, evenly								

Feb. 2–15, 1955; 11 nights	Side by side, evenly spaced through 1–acre plot	Oak-pine forest	*Peromyscus leucopus*	1649	(1) 1	1649	3 —	1649	
Mar. 1–11, 1955; 11 nights	Side by side, evenly spaced through 1–acre plot	Pure pole-sized pine stand	*Peromyscus leucopus*	1649	1 —	1649	—	1649	1
Mar. 31–May 9, 1955; 15 nights	Side by side in arc at approx. 20 ft. intervals	Oak-pine forest	*Peromyscus leucopus*		2(1)		--		1
			Peromyscus sp.	1496	—	1496	—	1496	1
May 26–June 6, 1955; 11 nights	Side by side, 2 rows of 25 groups, on each side of fire lane at 20 ft. intervals	Oak-pine forest	*Blarina brevicauda*	547	—	547	—	547	1
June 22–July 11, 1955; 10 nights	Side by side, 2 rows of 50 groups, on each side of power line break at 20 ft. intervals	Oak-pine forest with old field edge	*Peromyscus leucopus*		1		—		1
			Reithrodontomys fulvescens	990	—	990	—	990	1
Nov. 23–Dec. 2, 1955; 5 nights	Side by side in 500-yard line of 78 groups	Oak-pine forest	*Peromyscus leucopus*		—		1		
			Peromyscus nuttalli	331	3	331	—	331	5
			Reithrodontomys fulvescens		1				
			Oryzomys palustris		—		1		
			Totals	10110	40(22)	9660	12(4)	7412	17
			Catches		40		12		17
			Catches plus recatches		62		16		†
			Catch/1000 trap nights‡		5.6		1.7		2.3

* Number of recatches in parentheses.
† No valid comparison without possibility of recatches.
‡ Rounded to nearest whole number.
N.O. Traps not operating.

adjacent to unbaited ones may have attracted the animals into the vicinity of the unbaited trap where chance collission or investigation of the trap mechanism may have resulted in catches. Our results with water traps (Table 1) similarly indicate more success by water traps in the vicinity of baited snap traps than by unbaited water traps with no baited snap traps nearby. The bait in itself would appear to influence the movements of the animal although inherent cautiousness may have prevented their entrance into baited traps. On the other hand, as shown by experiments with captive shrews (Fowle and Edwards, *ibid.*), the type of bait used may play a considerable part in overcoming any trap-wariness exhibited by the animal.

Where a measured acre plot was sampled alternately with Sherman and Young live traps (Table 2) it is possible that the success of traps used in the second trapping session could have been reduced by mortality in the first trapping session (Manville, 1950). No evidence of such mortality was obtained directly but, if handling of animals caught in the first session contributed to their subsequent mortality, it could have contributed to an apparent decline in trapping success in the second session provided that no repopulation of the area occurred in the interval between trapping periods.

It would seem that the best method of comparison, as employed to a large extent in this study, is that in which different types of traps are placed side by side in identical locations where they are exposed to similar meteorological conditions and surrounding population density. If a choice is made by the animal before it enters the trap the method should give a valid comparison of trap efficiency. If, on the other hand, the animal entered a trap at random in any one location the element of selectivity with respect to type of trap entered would be removed. It is possible that a certain amount of random entry of this sort did occur, but the combined results indicate either that the Sherman trap was entered more often than other types (Table 2) or that it was mechanically more sensitive or efficient than others used. As a small attracting portion of bait was placed at the entrance of the live traps the accessibility of bait was about equal between live traps and snap traps, although in order to be caught in live traps bait placed in the rear of the trap had to be searched for.

SUMMARY

Different arrangements of traps and different types of traps were compared in an effort to determine the relatively most efficient type(s) of small mammal trap(s) for general purpose small mammal trapping to secure specimens and population data. Throughout most of the study variables affecting comparisons, such as trap location, meteorological conditions and type of bait used, were eliminated as much as possible.

It was shown that snap traps were relatively inefficient as compared with live traps and about equally as efficient as water or "pit" traps, and that the Sherman trap gave an over-all better performance than the Young trap. The Wisconsin trap did not enter directly into any comparisons but was found inferior for general field use in preliminary experiments.

Other types of mammal traps used chiefly to procure medium-sized mammals were compared briefly but no definite conclusions were drawn as to their relative efficiency.

LITERATURE CITED

BAUMGARTNER, L. L. 1940. Trapping, handling, and marking fox squirrels. Jour. Wildl. Mgt., 4: 444–450.

BLAIR, W. F. 1941. A simple and effective live trap for small mammals. J. Wildl. Mgmt., 5: 191–193.

CHRISTIAN, J. J. 1936. Mammals caught in post holes. Jour. Mamm., 17: 416.

CLARKE, C. H. D. 1938. A study of the mammal population of the vicinity of Pancake Bay, Algoma District, Ontario. Nat. Mus. of Canada, Bull. 88, Biol. Serv. 23: 141–152.

COCKRUM, E. L. 1947. Effectiveness of live traps versus snap traps. J. Mamm., 28: 186.

COTTAM, G. AND J. T. CURTIS. 1949. A method for making rapid surveys of woodlands by means of pairs of randomly selected trees. Ecology, 30: 101–104.

EDWARDS, R. Y. 1952. How efficient are snap traps in taking small mammals? Jour. Mamm., 33: 497–498.

FITCH, H. S. 1954. Seasonal acceptance of bait by small mammals. Jour. Mamm., 35: 39–47.

FOWLE, C. D. AND R. Y. EDWARDS. 1954. The utility of break-back traps in population studies on small mammals. Jour. Wildl. Mgt., 18: 503–508.

GEIS, A. D. 1955. Trap response of the cottontail rabbit and its effect on censusing. Jour. Wildl. Mgt., 19: 466–472.

GOODNIGHT, C. J. AND E. J. KOESTNER. 1942. Comparison of trapping methods in an Illinois prairie. Jour. Mamm., 23: 435–438.

GOODPASTER, W. W. AND D. F. HOFFMEISTER. 1954. Life history of the golden mouse, *Peromyscus nuttalli*, in Kentucky. Jour. Mamm., 35: 16–27.

HOLDENREID, R. 1954. A new live-catch rodent trap and comparison with two other traps. Jour. Mamm., 35: 267–268.

HOWARD, W. E. 1953. A trigger mechanism for small mammal traps. Jour. Mamm., 34: 513–514.

MANVILLE, R. H. 1950. A comparison of trapping methods. Jour. Mamm., 31: 377–383.

PRINCE, L. 1941. Water traps capture the pigmy shrew (*Microsorex hoyi*) in abundance. Canad. Field Nat., 55: 72.

QUAST, J. C. AND W. E. HOWARD. 1953. Comparison of catch of two sizes of small-mammal live traps. Jour. Mamm., 34: 514–515.

TANAKA, R. 1952. Theoretical justification of the mark-and-release index for small mammals. Bull. Kochi Women's College, 1: 38:47.

———. 1956. On differential response to live traps of marked and unmarked small mammals. Annot. Zool. Japonenses, 29: 44–51.

VESTAL, A. G. 1949. Minimum areas for different vegetations; their determination from species-area curves. Ill. Biol. Monogr., 20: 1–129.

YOUNG, H., J. NEESS AND J. T. EMLEN, JR. 1952. Heterogeneity of trap response in a population of house mice. Jour. Wildl. Mgt., 16: 169–180.

YOUNG, H., R. L. STRECKER AND J. T. EMLEN, JR. 1950. Localization of activity in two indoor populations of house mice, *Mus musculus*. Jour. Mamm., 31: 403–410.

Zoology Dept., Univ. of Arkansas, Fayetteville. Received December 8, 1956.

THE REPRODUCTIVE CYCLE OF THE FEMALE MOUNTAIN BEAVER

BY E. W. PFEIFFER

Since the mountain beaver, *Aplodontia rufa*, is conceded to be the most primitive living rodent, it is particularly important to know the pattern of reproduction in this species. The literature, however, contains limited information on this animal's reproduction. Asdell's review (1946) contains one brief reference to *Aplodontia*. Scheffer (1929) presented the fullest account of reproduction of this species, and Hubbard (1922) gave valuable reproductive data amid inaccuracies. There are excellent but limited descriptions of the anatomy of *Aplodontia*, including the reproductive tracts, by Tullberg (1896, 1899), and

Pfeiffer (1956) has described the gross and microanatomy of the male reproductive tract, including age and seasonal fluctuations. Harvey (1956) has compared the morphogenesis of fetal membranes of *Aplodontia* with those of *Ochotona*. The purpose of this paper is to outline some of the major anatomical and physiological features of the reproductive cycle of the female.

Methods.—Animals were trapped by the author in steel-jaw traps set in runways. In addition, a large number of specimens from the Seattle, Washington, area were supplied by Dr. V. B. Scheffer, who preserved the carcasses in 10 per cent formalin for shipment to Berkeley. Two hundred and eighty-nine animals were obtained from various localities as follows:

Area trapped	*Number trapped*
Olympic Peninsula	8
Seattle environs	152
British Columbia:	
Skagit Valley	10
Manning Park	2
Oregon	20
Point Arena, Mendocino County, California	2
Point Reyes, Marin County, California	79
Lake Tahoe, Placer County, California	6
Humboldt County, California	10
Total	289

The reproductive tracts of all animals were removed and the different organs measured to the nearest 0.5 mm. Specimens were fixed either in 10 per cent formalin or Bouin's fluid, treated in the usual manner, and stained with hematoxylin and eosin. In addition to the study of dead specimens, several live animals were observed in the laboratory for prolonged periods. Young animals grew well and adults gained weight during captivity even after they had been injured in the traps. They have also recovered completedly from such operations as ovariectomy and epididymal biopsy.

In *Aplodontia*, under five months old, age was estimated from body weights, using the growth curve of captive juveniles as a standard. For older animals, estimation of the degree of closure of the distal epiphyseal femoral suture was a fairly reliable method of aging. Because all *Aplodontia* in a given area are born during a restricted period each year, the femoral epiphyseal sutures represent yearly age classes (Plate II, below). Class I included all animals under one year; Class II included all animals between their first and second year; Class III did not represent a whole year group, but probably represented animals at the end of their second year or early in their third year, since all Class III sutures were found between December and July; Class IV represented animals with no sutures and hence full-grown. Table 1 shows the frequency of these femur classes in two areas. This method of aging was supplemented by observations of the third molar which is not evergrowing but tends to wear down with age.

Gross anatomy of the female reproductive tract.—The gross anatomy of the

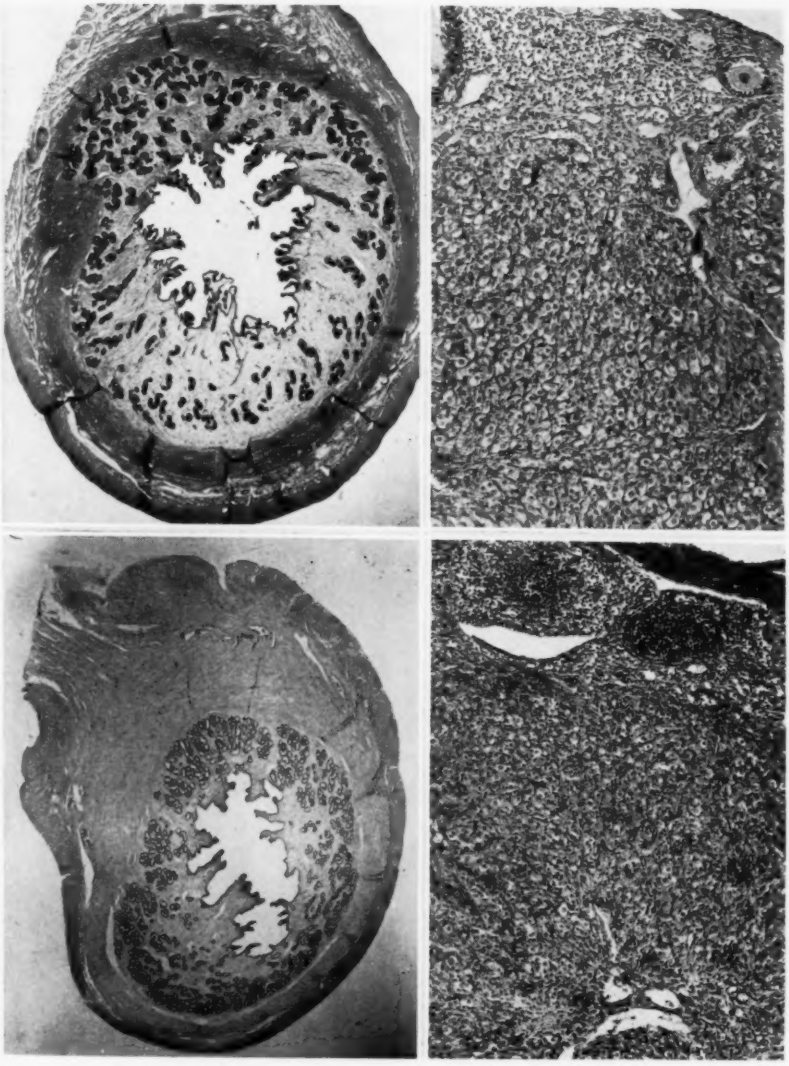

PLATE I

ABOVE: Left—Uterus of a pregnant female at beginning of implantation; 5.7 ×. Right—Corpus luteum of early pregnancy; 35 ×. BELOW: Left—Uterus of a yearling, post-ovulatory, non-pregnant female; 5.7 ×. Right—Corpus luteum of the yearling whose uterus is shown at the left; 35 ×.

reproductive organs of the female is similar to that of many other rodents. The uterus is a typical duplex type. The urethra opens into the vagina so that a urogenital sinus is formed distal to this opening. The anestrous uterus is thread-like in nulliparous females and is easily distinguished from that of parous females. In the latter the uterus is a compressed, ribbon-like structure considerably larger in all respects than the nulliparous organ.

The oviduct is connected to the ovary by a short mesosalpinx which does not form a bursa around the ovary. However, in estrous females the fimbriae of the oviducts were enlarged and in one case partially enclosed the ovary, like fingers.

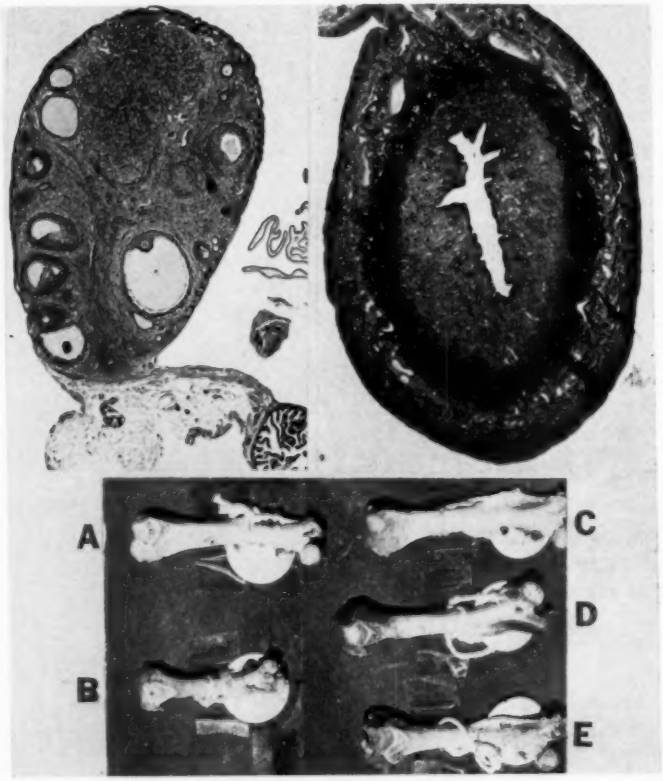

PLATE II

ABOVE: Left—Ovary of a pregnant female; 5 ×. Right—Uterus of a parous, anestrous female; 8 ×. BELOW: Femurs of various specimens; ¼ ×. *A*, Less than one year old, Class I; *B*, juvenile; *C*, with closed distal epiphyseal suture, Class IV; *D*, at end of second or beginning of third year, Class III; *E*, in second year, Class II.

TABLE 1.—*Frequency of four femur classes in two areas*

AGE	SUTURE CLASS	NUMBER OF INDIVIDUALS IN WASHINGTON SAMPLE	NUMBER OF INDIVIDUALS IN MARIN COUNTY SAMPLE
0–1 yr. (short yearling)	I	33	14
1–2 yr. (long yearling)	II	36	14
2 yrs. to 2 yrs. 4 mos.	III	7	3
Slightly over 2 yrs. to death	IV	63	27

The ovary is elliptical, compressed or rounded, and changes considerably in size during life (Fig. 1). In anestrus almost no follicular development can be seen macroscopically. Ovaries at estrus contain large follicles (up to 3 mm.) and in postovulatory females, particularly pregnant ones, corpora lutea formed reddish swellings. However, some corpora are not evident at the surface and can only be detected by histological examination. The fertility and fecundity of females were estimated by examination of ovaries and uteri (Table 2). There is little loss of ova or embryos between ovulation and implantation.

The female pelvis is practically indistinguishable from that of males. There was no specific hormonal effect on the pubic or sacroiliac symphyses during pregnancy, as occurs in many rodents. Pelves of first-year animals of both sexes are relatively narrower between the iliac crests than in older animals, and the union between the pubes consists of cartilage joined with ligament. In full-

TABLE 2.—*Fertility and fecundity of females*

NUMBER OF FEMALES EXAMINED	NUMBER OF CORPORA LUTEA		NUMBER OF EMBRYOS	
	Right	Left	Right	Left
With corpora lutea and embryos 12	17	17	11	18
Average/side	1.4	1.4	.9	1.5
Maximum/side	2	3	2	4
Average/animal	2.8		2.4	
Maximum/animal	3.1		4.0	
			NUMBER OF PLACENTAL SCARS	
With corpora lutea and placental scars 3	0	8	0	8
Average/side	0	2.7	0	2.7
Average/animal	2.7		2.7	
Total with placental scars 25	–	–	26	37
Average/side			1.0	1.5
Average/animal			2.5	
			CORPORA/ANIMAL	
With corpora but not pregnant 7			2.6	

grown animals of both sexes, cartilage is replaced by bone and ligamentous material.

Externally, the reproductive organs of the female consist of a small clitoris, the opening of the urogenital sinus, and three pairs of mammary glands. The vagina is always patent. The pectoral pair of mammae is located just anterior to the axilla and is often the most used during lactation. The thoracic pair is also commonly used while the third pair, located abdominally, is sometimes not nursed. Progestational, gestational and lactating females show dark patches of hair around the nipples. This phenomenon has been described in detail by Pfeiffer (1955). Except at estrus, parous females can be distinguished from nulliparous females by their much longer, pendant nipples.

Ovarian and uterine cycles.—The youngest ovary examined was that of a 38-mm. C–R fetus (9.4 gms.). Wolffian ducts were barely evident in the mesentery and large cells, probably degenerating primordial ova, were seen in an undifferentiated stroma. A second, older fetus (58 mm. C–R, 10 gms.) showed well-differentiated oögonia. There was no evidence of prenatal hormonal stimulation such as occurs in some mammals.

Ovaries of juveniles about two months old contained many oöcytes in all stages of growth from oögonia to primary follicles, but no larger follicles and no hypertrophied interstitial tissue. The uterus was threadlike with a thin myo-

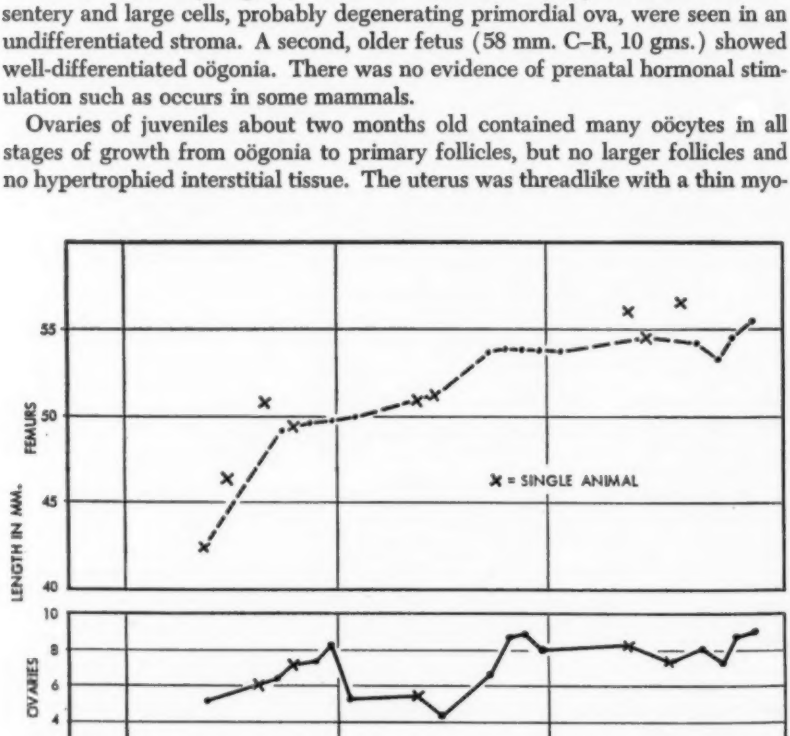

FIG. 1.—Seasonal and age changes in length of ovaries and age changes in length of femurs of a Seattle, Washington, population of *Aplodontia*.

metrium and a shallow, dense endometrium having a low columnar epithelium and slight glandular invasion. The ovaries of a five-month-old juvenile, removed two weeks after capture, had intermediate follicles with small antra, some with mitotic figures in the granulosa cells and others becoming atretic, and many smaller follicles. Some stromal cells were hypertrophied. This animal had a turgid uterus, the myometrium was vascular, the endometrium was edematous, and proliferation of glands had occurred in the latter. The uterine lining was thrown into a few simple ridges less well developed than in the estrous animal.

An eight-month-old juvenile also showed evidence of a previous period of heightened ovarian and uterine activity.

Toward the end of their first year the ovaries of young females begin to enlarge (Fig. 1) as adult females come into estrus. The yearling ovary shows active follicular development and much hypertrophied interstitial tissue probably derived from theca interna cells of atretic follicles. First meiotic divisions were evident in some large atretic follicles. Certain yearling females ovulated, but others showed little sexual activity. Two tubal ova were found in one yearling. They were not surrounded by a corona radiata and were from 90 to 100μ in diameter outside the zona pellucida. No spermatozoa were found in the tubes.

The typical early corpus luteum of yearlings resembles the corpus of pregnancy but it is smaller, and there are sinus-like blood vessels interspersed throughout the gland, which were never found in the latter. The cells of older corpora of yearlings are smaller than those of pregnant females (Plate I) and there is much hypertrophied interstitial tissue in the ovary. None of the corpora of yearlings were clearly visible macroscopically.

At ovulation the yearling uterus is enlarged due to increased thickness of the myometrium and edema and swelling of the endometrium, which is thrown into low ridges and folds. There are many coiled glands. The post-ovulatory uterus of the yearling shows some evidence of progesterone stimulation but arborization does not reach the degree of development that is found in adult post-ovulatory animals (Plate I). The latter generally become pregnant while the former do not.

The period of sexual activity of young females apparently does not extend beyond the estrous period of adults since no traces of corpora lutea were found in five yearling females taken in April and early May. These long yearlings show no sexual activity until the late or early winter of their second year. The ovaries begin to hypertrophy again (Fig. 1), and from four to six weeks after the first ovarian activity is noted, corpora lutea are found.

In animals two years old and older, ovulation usually leads to pregnancy and the formation of the corpus luteum of pregnancy. At implantation a slight uterine swelling is noticeable and the antrum of the corpus has been almost completely luteinized. In contrast to ovaries of post-ovulatory yearling females, there is little hypertrophied stromal tissue except for thecal glands around the

corpora and larger follicles (Plate II). The ovary near term has the largest corpora and lutein cells of the cycle, and very large atretic follicles.

Regression of the corpora proceeds at a rapid rate after parturition. Two very early post-parturitional females showed ovaries in which the corpora were barely visible and the lutein cells were completely atrophied. A female with young probably not over three weeks old had no corpora and follicular activity was slight. The ovaries of females which had young about two months old showed almost no follicular development.

In adult females prior to implantation the endometrium becomes very edematous, and arborization of its surface is well developed. The muscle layers are greatly hypertrophied and there is much vascularity so that the diameter of the uterus of early pregnant females is greater than that of post-ovulatory yearlings.

In the fall there are three size classes of uteri that represent fairly accurately three age classes of females: short yearlings, long yearlings (both nulliparous), and parous females, the majority of which are over two years old. These classes had the following average dimensions during the anestrous period:

Age	*Suture class*	*Mean dimesions, mm.*		*Number of uteri*
		Obmesometrial	*Mesometrial*	
Short yearling	1	0.78	0.87	6
Long yearling	2	1.2	1.8	3
Over 2 yrs. old	4	1.6	4.1	4

In addition to its greater size, the parous, anestrous uterus (Plate II) is more heavily vascularized than the nulliparous and there is a clearly defined stratum vasculare between the inner circular and outer longitudinal layers of muscle.

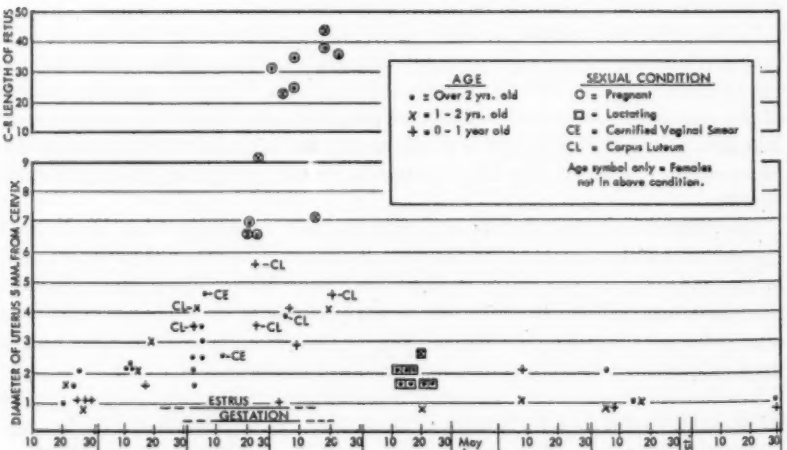

FIG. 2.—Age, sexual condition, and size of uterus or fetus of female *Apodontia* of a Seattle, Washington, population plotted with reference to the date of their capture.

While most of the adult females (femur Class II to IV) become pregnant, two such females had ovulated but were almost certainly not pregnant. The corpora of these animals resembled the corpora of early post-parturitional females except that luteinization had not occurred completely. Endometrial proliferation in these animals resembled that of pregnant females.

Several ovaries showed vestigial tubules at the hilus, probably remains of the rete ovarii. Cystic rete ranged from about 2 mm. to 20 mm. in diameter. One female had a very large rete cyst in each ovary. None of the females with rete cysts were pregnant although some showed much ovarian activity.

Estrus.—The estrous female is characterized externally by hypertrophied nipples, a greatly swollen vulva, and a vaginal smear showing a cloud of cornified epithelial cells. (The anestrous smear is mainly nucleated cells with some leucocytes.) Changes in composition of the vaginal smear occurred as follows in an isolated, captive, yearling female:

Date	*Cellular composition of smear*
February 2	Cornified epithelium (C.E.)
5	Cornified epithelium
8	Many leucocytes (L.), few nucleated epithelium (N.E.)
12	L., N.E., C.E.
13	Many C.E., some N.E., L.
15	Mostly L., few C.E.
18	Few L., many C.E., some N.E.
19	Mostly C.E., some N.E.
25	C.E.

This animal's ovaries, removed soon after the study of its vaginal cycle, failed to reveal any evidence of ovulation, although the uterus showed much glandular proliferation resembling the estrous uterus of wild females. It seems, therefore, that this individual almost ovulated and exhibited a cyclic rise and fall of ovarian activity generally associated with spontaneous ovulators.

Gross examination of the internal reproductive tract at estrus reveals greatly enlarged uterus and cervix. One or two large follicles (1.5–3.0 mm.) are visible at the surface of the ovary. The microanatomy of the tract at estrus has been described above.

Using the above criteria, it was determined that estrus occurs within a short period of from 5–7 weeks in mid- or late winter. Fig. 2 depicts graphically the events that occur in the sexual life of the females of the Washington subspecies.

A similar length of time for ovulation is indicated by less extensive data for the Marin County subspecies. The data, obtained during three years of trapping, indicate that ovulation occurs at about the same time each year for a given population.

Sterile cycle in yearlings.—Yearling females may undergo a sterile estrous period one year prior to becoming fertile. Since this is a somewhat unusual and important phenomenon, further evidence to support this conclusion is presented. Scheffer (1929) and Hubbard (1922) suggested that first-year animals do not breed, and Scheffer identified this age class on the basis of weight. Using the

degree of closure of epiphyseal sutures, it was possible to determine in most cases whether these small, non-pregnant females were young or small mature adults.

In analyzing the age and sexual condition of females of the 1953 Seattle sample, specimens taken between February 20 and May 1 were put into two classes: pregnant or lactating, and those showing no indication of pregnancy. The latter class may be composed of nulliparous females or parous females that did not become pregnant. All the non-pregnant females from the 1953 Washington sample fell into the former category as judged by nipples, appearance of the uterus, etc. The weights of these two classes averaged as follows:

	15 pregnant or lactating ♀♀	*6 nulliparous ♀♀*
Mean weight, oz.	38.1	28.9
Range	33–47	27–31

The nulliparous animals were, therefore, smaller than the parous. The smaller animals were also younger as revealed by the following:

Femur class	*Number of lactating or pregnant females* (Washington)	*Number of nulliparous females* (Washington)
Class IV	3	0
Class III	3	0
Class II	6	1?
Class I	0	6

Some of those parous females in Class II may be in the same age class as the six nulliparous females. Thus, it is possible that some first-year females become pregnant, but it is certain that many yearlings do not become pregnant. A similar situation is apparent from the less precise data from other areas and from supplementary data obtained in Seattle during February and March, 1954. The reproductive tracts and femurs of 19 females gave the following information:

Suture class	*Number pregnant*	*Number showing ovarian activity but not pregnant*	*No activity*
I	–	3	3
II	–	3—two had ovulated (one resorbed embryo)	–
IV	5	5—one had ovulated	–

Since a considerable number of females do not become pregnant, as it has been shown that ovulation occurs in many of these females, and since no evidence of copulation, such as sperm in the female tract, was ever found, it seems logical to surmise that ovulation is spontaneous.

The sterile estrous cycle in yearlings is correlated with a distinctive characteristic of the growth curve. Fig. 1 shows by femur lengths that there is a long period of greatly retarded growth during the first year. Despite the fact that there is sex activity, undoubtedly resulting in some estrogen production, during this period, epiphyseal sutures do not close until the following year. During this time there is a further growth period and pregnancy usually occurs. The pattern differs from that of many mammals in which the growth-spurt accompanies the onset of sexual activity, and the production of estrogen subsequently terminates growth by fusing sutures (Hooker and Pfeiffer, 1943).

It is possible that lack of growth in combination with unfused epiphyses is related to the inability of the yearling females to become pregnant even though they ovulate. This syndrome resembles that ascribed to hypopituitarism in certain mammals.

Pregnancy.—Indirect evidence indicates that the period of gestation is 28–30 days. Most of the Seattle, Washington, sample had early embryos during the last half of February and had large fetuses about the first of March. Very early post-parturitional females were captured about the middle of March (Fig. 2). All but one of the dates of capture of the pregnant or post-parturitional females of the Washington sample fall on the curve depicting female sexual activity at such positions as to indicate that the gestation period is about one month. In the Marin County area dates of ovulation and parturition have also been estimated, and the time between these two events is about one month.

Recovery of near-term fetuses and recently post-parturitional females, and calculation of birth dates of juveniles using known growth curves, gives approximate dates of parturition in different areas (Fig. 3).

At parturition little decidual tissue is shed. The recent post-parturitional uterus shows large (1 cm. diameter) placentation areas, which regress quickly

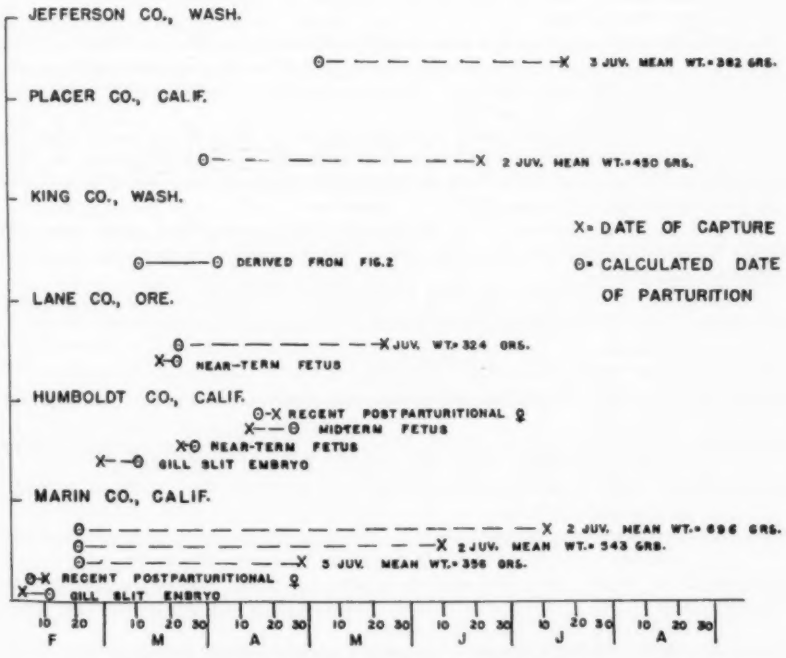
JEFFERSON CO., WASH.
3 JUV. MEAN WT.= 382 GRS.
PLACER CO., CALIF.
2 JUV. MEAN WT.= 450 GRS.
KING CO., WASH.
X= DATE OF CAPTURE
DERIVED FROM FIG.2
Θ= CALCULATED DATE OF PARTURITION
LANE CO., ORE.
JUV. WT.= 324 GRS.
NEAR-TERM FETUS
HUMBOLDT CO., CALIF.
RECENT POST PARTURITIONAL ♀
MIDTERM FETUS
NEAR-TERM FETUS
GILL SLIT EMBRYO
MARIN CO., CALIF.
2 JUV. MEAN WT.= 696 GRS.
2 JUV. MEAN WT.= 543 GRS.
5 JUV. MEAN WT.= 356 GRS.
RECENT POSTPARTURITIONAL ♀
GILL SLIT EMBRYO
10 20 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30
F M A M J J A

FIG. 3.—Estimated dates of parturition of *Aplodontia* in various areas.

during lactation. Before the end of lactation the uterus shows the typical anestrous condition. A nursing female had placental scars that were small, hard, pigmented swellings consisting of an endometrium with dense, much vascularized, non-glandular stroma and a low epithelium. Placental scars are barely visible macroscopically until early fall when they become obscured by the gradual hypertrophy and hyperplasia of the uterus as estrus approaches.

Lactation probably does not continue beyond two months since juveniles of that age had much vegetable matter in their stomachs.

Discussion.—Comparing the main features of the female *Aplodontia* anatomy and sexual cycle, such as short estrous period once a year, no post-partum heat, slow onset of sexual maturity, length of gestation, fecundity, and microanatomical changes in the reproductive tract, with similar features of the cycle in other rodent groups, it is apparent that the reproductive physiology of *Aplodontia* closely resembles that of certain sciurids. Deanesly and Parkes' (1933) description of the estrous cycle in *Sciurus carolinensis* reveals many basic similarities to *Aplodontia.*

SUMMARY

Aplodontia has a low reproductive rate because it usually does not bear young until it is two years old, produces only one litter per year, and has few young per litter.

Conception occurs during only a few weeks in the year because of the very short estrous period. All females that ovulate in a given population do so at about the same time each year so that there is a very sharply defined and extremely limited breeding season within a population. Evidence indicates that *Aplodontia* ovulates spontaneously during a monestrous annual cycle, but the evidence is not conclusive.

Since the growth curve of the young maintains a plateau at about 75 per cent of adult size for several months, and since during this period there is sterile production of some ova (i.e., ovulation not leading to pregnancy) it is postulated that *Aplodontia* has a period of low pituitary function during its first year of life.

Comparing the main features of the female *Aplodontia* anatomy and sexual cycle with similar features of the cycle in other rodent groups, it is concluded that *Aplodontia* closely resembles certain sciurids.

Acknowledgments.—I wish to thank Dr. O. P. Pearson for his invaluable assistance during this study, and Dr. Victor Scheffer for his help in obtaining specimens of *Aplodontia rufa.*

LITERATURE CITED

Asdell, S. A. 1946. Patterns of mammalian reproduction. Comstock Publishing Co., Ithaca, N. Y.

Deanesly, R. and A. S. Parkes. 1933. The estrous cycle of the grey squirrel (*Sciurus carolinensis*). Philos. Trans. Roy. Soc. London, Ser. B, 222: 47–96.

Harvey, E. B. 1955. Placentation in Ochotonidae and Aplodontidae. Ph.D. thesis, Univ. of California, Berkeley.

Hooker, C. W. and C. A. Pfeiffer. 1943. Effects of sex hormones upon body growth, skin, hair and sebaceous glands in the rat. Endocrin., 32: 69–76.

Hubbard, C. A. 1922. Some data upon the rodent, *Aplodontia.* Murrelet, 3: 14–18.

Pfeiffer, E. W. 1955. Hormonally induced mammary hairs of a primitive rodent, *Aplodontia rufa.* Anat. Rec., 122: 241–256.

———. 1956. The male reproductive tract of a primitive rodent, *Aplodontia rufa.* Anat. Rec., 124: 629–638.

SCHEFFER, T. H. 1929. Mountain beavers in the Pacific northwest. Farmers' Bull. 1598, U.S.D.A., 1–18.

TULLBERG, T. 1896. Zur anatomie des *Haplodon rufus*. Festschrift f. Lilljeborg, Upsala, 231–251.

———. 1899. Uber das system der Nagethiere. Nova Acta Reg. Soc. Upsala, Ser. III, 18(1).

Museum of Vertebrate Zoology, Univ. of Calif., Berkeley. (Present address: Dept. of Anatomy, Univ. of N. Dak., Grand Forks.) *Received February 7, 1957.*

THE DISTRIBUTION AND MOVEMENT OF SMALL MAMMALS IN CENTRAL OKLAHOMA

BY HORACE A. HAYS

The distribution and movement of mammals has been the subject of much interest and research. Some mammals are known to range widely in search of food and mates while others live their entire lives in a relatively small area. This movement, as revealed by various methods of trapping or marking and recapturing the same animal, was studied even when live traps were only tin cans, glass bowls and buckets (Bailey, 1921).

The purpose of the present investigation was to secure information on the distribution, relative abundance and natural movements of small mammals, especially rodents, in two vegetative types (open grassland and wooded ravine) and to determine whether they move into and out of the two areas. Since both live traps and snap traps were utilized in the capture of small mammals, it was further desired to compare the effectiveness of the two methods of trapping in each vegetative type. The investigation was initiated on September 1, 1952, and was carried on continuously for one year.

Study area.—The area used in the live-trap study is located approximately 7 mi. SW Norman, Oklahoma, along State Highway 9, in Sec. 8, T. 8 N, R. 3 W, in McClain County (Fig. 1). The area utilized in snap trapping and other investigations is located within a radius of 4 miles of the live trap area. It is believed that the area selected for carrying out all investigations is typical of the tall-grass prairie of today with respect to topography, exposure, soil, stream course and other natural factors.

The area studied lies in the mixed-grass plains biotic district of Blair and Hubbel (1938). It is a part of the Texan biotic province of Dice (1943). Carpenter (1939) described the tall-grass prairie as an area of distinct ecotone, the general transition from the eastern deciduous forests to the grasslands of the Great Plains.

In general the area studied is a rolling plain of broad, flat-topped ridges separated by wooded ravines. The underlying rocks are soft, red shales and thin, red sandstones of Permian origin. The soils are of considerable depth and moderately fertile. The region is subject to variable and extreme climatic condi-

tions: strong, dry winds, dust storms and sudden changes in temperature are frequent. The average annual rainfall in this area is 33.22 in. and the average annual temperature is 64.8°F., as recorded over a 50-year period at Norman by the U.S. Weather Bureau. From September, 1952 through August, 1953 the precipitation at Norman was 28.42 in. which was 4.80 below normal. The average temperature at Norman for this one-year period was 69.1°F., which was 4.3° above normal (U.S. Dept. Comm., 1952 and 1953). The growing season is approximately 210 days (Bruner, 1931).

The open grassland involved in this investigation is representative of the grazed pasture land or revegetating abandoned land of the tall-grass prairie region. The dominant grasses in the relatively undisturbed portion of the grassland area studied are little bluestem (*Andropogon scoparius*), Indian grass (*Sorghastrum nutans*), big bluestem (*Andropogon Gerardi*) and switch grass (*Panicum virgatum*). Various other species appear as seasonal dominants. Kelting (1954), in his study of a grazed pasture in the same general area, designated *Andropogon scoparius* and *Sorghastrum nutans* as dominant species. Welch (1929) and Bruner (1931) found similar results in their investigations of the same area. Weaver and Clements (1938) stated that the true prairie, or *Stipa-Koeleria* association, extended into this area and that little bluestem (*Andropogon scoparius*) was the dominant plant and grew in pure stands except where local unfavorable conditions resulted from erosion or heavy grazing. Many of the grasses and forbs found in the area are indicators of disturbance. Some of these found to be common are *Opuntia* spp., *Buchloe dactyloides*, *Chloris verticillata* and *Bromus* spp. Kelting (1954) listed several in his investigations of disturbance in a grazed pasture in the same vicinity.

The ravines of the study area are wooded, the common trees being the American elm (*Ulmus americana*), post oak (*Quercus stellata*), persimmon (*Diospy-*

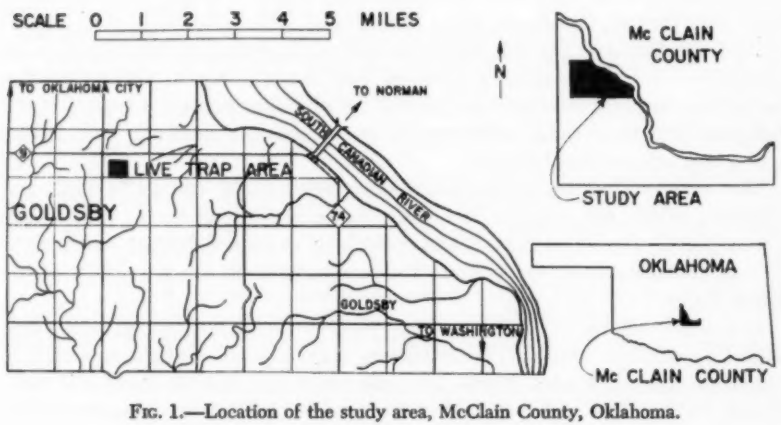

FIG. 1.—Location of the study area, McClain County, Oklahoma.

ros virginiana), wild plum (*Prunus* sp.) and redbud (*Cercis canadensis*). Bruner (1931) and Blair and Hubbell (1938) listed these same trees as being common in this region. However, the black walnut (*Juglans nigra*) which they listed as common was found only occasionally in the particular area studied and the post oak (*Quercus stellata*) was more common than either seemed to indicate. An intermixture of oaks—mostly blackjack (*Quercus marilandica*), post oak (*Quercus stellata*) and shin oak (*Quercus* sp.)— covers the slopes of the ravines. The most important shrubs are smooth sumac (*Rhus glabra*), winged sumac (*Rhus copallina*), poison sumac (*Rhus radicans*) and buckbrush (*Symphoricarpos orbiculatus*). Bruner (1931) found the same shrubs common in the area. Grape vines (*Vitis* spp.) and green briar (*Smilax* spp.) are found in abundance throughout the area studied.

MATERIALS AND METHODS

Most of the snap trapping was done with standard Museum Special traps. However, some Victor rat traps and special traps for gophers and moles were used. Some small mammals were taken by means other than trapping during the study. Trapping procedure was standardized as far as possible in order to get comparable data from month to month and from season to season. (As used in this paper the seasons are designated as follows: winter—December, January and February; spring—March, April and May; summer—June, July and August; fall—September, October and November.)

Trapping was begun in September, 1952, and was carried on continuously for twelve months with an equal number of traps being set each month in both wooded ravine and open grassland. Every setting was made in the late afternoon and the trap line was run early each morning before the temperature became warm. The number of traps set on each trapping night varied from 25 to 100 with from 200 to 330 set in each vegetative type each month.

Two types of metal live traps were used, the Havahart size "O" and a larger size small-mammal trap from Montgomery Ward & Co. On the whole the former type proved more effective. The technique used in live trapping followed closely that recommended by Blair (1941). Thirty-six live traps were used with three rows of twelve traps each, half of the traps located in the open grassland and half in the wooded ravine. The traps were set in a grid pattern, 40 feet apart. The trapping routine consisted of visiting the traps twice a day for four days each week from October 16, 1952 to October 15, 1953. The traps were left unset during the day in hot summer months and during periods of extreme cold in the winter, in an attempt to keep trap mortality to a minimum. Various baits were used throughout the period, but the most effective baits were rolled oats, a mixture of rolled oats and peanut butter, and sunflower seeds. A small wad of cotton, which served as nesting material, was placed in each trap. The mammals caught in the live traps were marked by the toe-clipping method (Burt, 1940). Complete field notes were kept for each mammal captured. Each animal was set free at the place of capture after being marked or examined. By this method monthly and seasonal data were obtained.

RESULTS

Snap trapping.—The number of small mammals taken in snap traps and the per cent capture per trapnight were three times as great in the open grassland as in the wooded ravine (Table 1). The results of the snap trapping showed *Peromyscus maniculatus, Perognathus hispidus* and *Sigmodon hispidus* to be the most common small mammals in the open grassland, while *Peromyscus leucopus* and *Neotoma floridana* were most common in the wooded ravine. The monthly distribution of mammals taken in snap traps showed that the greatest number of captures in the open grassland was in October and the lowest in August, whereas

TABLE 1.—*Numbers and kinds of small mammals taken in snap traps in two habitats during the 12-month period*

VEGETATION TYPE	NUMBER OF TRAPS SET	NUMBER OF MAMMALS TAKEN	PERCENTAGE CAPTURE PER TRAPNIGHT	SPECIES TAKEN MOST OFTEN
Open grassland	2,615	119	4.5	*Peromyscus maniculatus*, *Perognathus hispidus* and *Sigmodon hispidus*
Wooded ravine	2,615	36	1.3	*Peromyscus leucopus* and *Neotoma floridana*

in the wooded ravine the greatest number of captures was in May and the lowest in August and November. The greatest number of mammals taken in the open grassland was in the fall with a seasonal low in the summer, whereas the seasonal high in the ravine was in the spring with the low in the summer.

Live trapping.—The number of small mammals taken in live traps and the per cent capture per trapnight were also each three times as great in the open grassland as in the wooded ravine (Table 2). The results substantiated those of snap trapping in that they also showed *Peromyscus maniculatus*, *Sigmodon hispidus* and *Perognathus hispidus* to be the most common small mammals in the open grassland and *Peromyscus leucopus* and *Neotoma floridana* most common in the wooded ravine. The monthly distribution of mammals taken in live traps in the two areas showed that the greatest number of captures and recaptures in the open grassland was in August and the lowest in December, while in the wooded ravine the greatest catch was in January and the lowest during March, May and November. The greatest mammalian activity in both associations occurred in the summer, but the least activity in the grassland was during the winter and in the ravine during the spring.

During the twelve-month trapping period, 54 small mammals were marked and released at the place of capture in the live-trap area. Of that total, 33 were recaptured one or more times: 10 were retaken once; 2, six times; 3, seven times; 2, eight times; 1, eleven times; and 1, fourteen times. The longest interval between initial capture and final recapture was five months and one day, the mammal being a cotton rat in the open grassland (Fig. 2). Two mammals, one a cotton rat and the other a deer mouse, were retaken after intervals of more than three months.

A graphic sketch showing the movements or places of recapture of six mammals representing the different species retrapped one or more times in different live traps is shown in Figs. 2 and 3. It should be mentioned that three mammals were retaken only at theh original place

TABLE 2.—*Numbers and kinds of small mammals captured and recaptured in live traps in two habitats during the 12-month period*

VEGETATION TYPE	NUMBER OF TRAPS SET	NUMBER OF MAMMALS TAKEN	PERCENTAGE CAPTURE PER TRAPNIGHT	SPECIES TAKEN MOST OFTEN
Open grassland	2,808	136	4.8	*Peromyscus maniculatus*, *Sigmodon hispidus* and *Perognathus hispidus*
Wooded ravine	2,808	45	1.6	*Peromyscus leucopus* and *Neotoma floridana*

of capture and, thus, no movement was indicated. The 32 males and 22 females—29 adults and 25 immatures—show an 18.5 per cent greater catch of males than of females and a 3.8 per cent greater number of recaptures of males. This would seem to support the idea that male rodents have a greater tendency to wander than do females. However, analysis of the data further indicates that average distance traveled by 16 males was 292.5 feet while that by 14 females was 302.9. Eleven immature rodents averaged 309.1 feet while 19 adults traveled 290.5. The data further indicate that there are only occasional movements by individuals of certain species of mammals inhabiting one vegetative type into the other vegetative type, and then only into the fringes.

Five small mammals—three cotton rats, one deer mouse and one wood mouse—were taken in live traps during the day. These three species appear to be somewhat active by day as well as by night. This supports to a limited degree the evidence of Johnson (1927) that deer mice are active during the daytime as well as during the night. Phillips (1936), in his study of the distribution of rodents in overgrazed and normal grasslands in central Oklahoma, reported that many cotton rats were taken during the diurnal period of the day.

DISCUSSION

During the year a total of 233 small mammals were collected and catalogued; of this number, 184 (79 per cent) were taken from the open grassland and 49 (21 per cent) from the

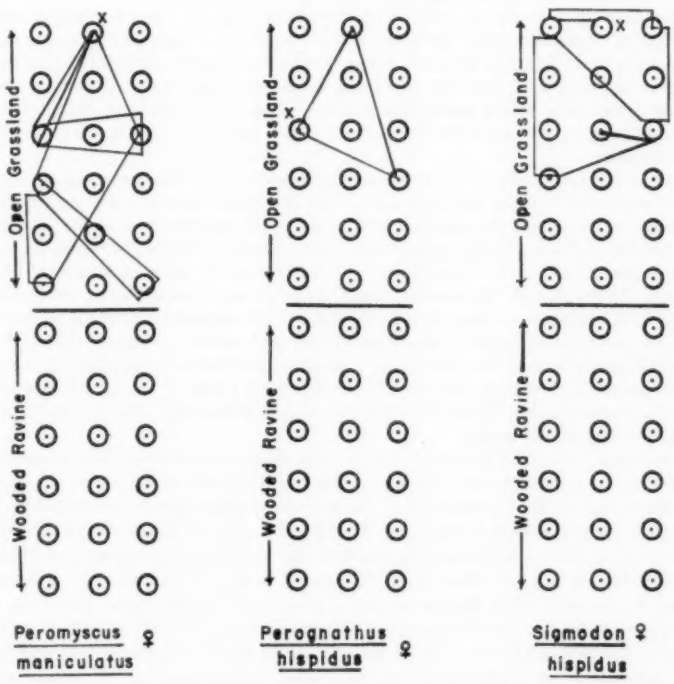

FIG. 2.—Representative movements of three live-trapped small mammals, all adults; these were the most abundant species found in the open grassland. Encircled dots indicate location of traps; *X* indicates point of first capture; distance between traps, 40 feet.

wooded ravine. Of the 233 mammals collected, 209 were taken by traps (155 in snap traps and 54 in live traps).

One of the objectives of this study was to determine the effectiveness of snap trapping and of live trapping as means of capturing small mammals. Results of both types of trapping showed that approximately three times as many small mammals were taken in the grassland as in the ravine and that by each method the same species were taken most often. These data indicate that the methods are equally effective if carried on for a period of one year.

Other investigators who have made comparative studies of snap trapping and live trapping do not seem to be in agreement as to the reliability of the two methods. Taylor (1930), in four days of trapping, found that certain species of rodents were caught more frequently in snap traps while others were taken more frequently in live traps. In his investigation pocket mice were caught in the same ratio; grasshopper mice were taken four times as often in live traps as in snap traps; while eight times as many kangaroo rats were secured in the snap traps as in the live traps. Goodnight and Koestner (1942) made a comparative study on two plots of land separated by a buffer zone, using live traps on one plot and snap traps on the other. As a further check the live-trap plot was later retrapped with snap traps. These men concluded that the two methods of trapping were equally reliable for indicating the size of populations. Gray (1943) used live traps and snap traps in a study of five quadrats and concluded that similar quadrats produced similar results with each type of trapping. He pointed out, however, that live traps and snap traps might not be mixed in the same quadrat with the expectation of equal results since the bait of the latter is more readily available. Stickel (1946) carried out tests designed to make a direct comparison of live trapping and snap trapping at the Patuxent Research Refuge in Maryland and found that the modern methods of live trapping were valid for population studies but that snap-trap methods were invalid for determining actual population numbers. She stated, however, that it should be practical to use a snap-trap quadrat technique to obtain a relative index figure for small mammal populations.

The seasonal distribution of the animals snap-trapped in the two areas was in agreement in so far as the seasonal low was concerned, since the fewest in each study area were taken in the summer. However, the seasonal high in the open grassland was in the fall, while in the ravine this high came in the spring. The seasonal high in the fall, as shown by the snap trapping, seemed to be more in agreement with the findings of other investigators. Hamilton and Cook (1945) stated: "Seasonably, small mammals are most numerous in the autumn when the year's young have been added and fewest in the springtime, after the winter's losses and before replacement begins." Hamilton (1942) and others have given reasons for relatively small populations in the winter, but a search of the literature supplied no explanation for a seasonal low in summer. It is possible that at least a part of the explanation concerns reaction of the mammals to the high temperature during this season. This is a problem which apparently needs greater study.

The live-trap record indicated that the greatest number of captures and recaptures was made during the summer in each vegetative type. It is difficult to determine the causes for this seasonal high in the live traps when the snap-trap record showed a seasonal low. Perhaps a part of the explanation may lie in the fact that some of the mammals used the live traps as feeding stations and, consequently, this may not present an accurate picture of the actual distribution. On the other hand, the rainfall during the summer was unseasonably high, and it is possible that a smaller number of captures in the snap traps during this period may have resulted from rain interferring with snap trap results while it seldom set off the live traps. The seasonal lows in the winter and spring for the open grassland and wooded ravine, respectively, as shown by the live-trap data, seemed to be in agreement with the findings of Hamilton and Cook (1945).

By far the most abundant small mammal in the open grassland was *Peromyscus maniculatus*, of which 72 out of 119 were caught in 2,615 trapnights of snap trapping, and 66 out of 136

in 2,808 trapnights of live trapping. These mice were confined almost entirely to the grassland and were seldom taken in the ravine by either method of trapping.

Sigmodon hispidus was one of the three most abundant small mammals in the open grassland. Almost without exception cotton rats were taken in the tall grass along fence rows and terraces. Of a total of 13 captures in snap traps and 44 captures and recaptures in live traps, only two individuals were ever captured in the ravine, both of these in live traps.

There were 27 pocket mice collected in snap traps and 18 captured or recaptured in live traps. These represent 22.7 per cent of the 119 small mammals taken in snap traps and 13.2 per cent of the 136 captures and recaptures in live traps. This is one of the three most abundant small mammals restricted to the open grassland. These mice were found to be most common along terraces in grazed pasture land where, on October 26, eight of them were captured when only 75 snap traps had been set. No individual of this species was captured in or near the ravine by either trapping method. In all localities where this mouse was taken the deer mouse and cotton rat were also present.

Kangaroo rats (*Dipodomys ordi*) were taken only in the flood plains of the South Canadian River about 2½ mi. SW Norman, where several colonies were well established in the sandy, sparsely vegetated areas. Blair (1939) indicated that these rats inhabited sandy areas throughout western Oklahoma and that in some years they became quite numerous. Although no effort was made to study mammals of the flood plains, it would seem that a study of the life history of this subspecies (*oklahomae*) would make an interesting problem.

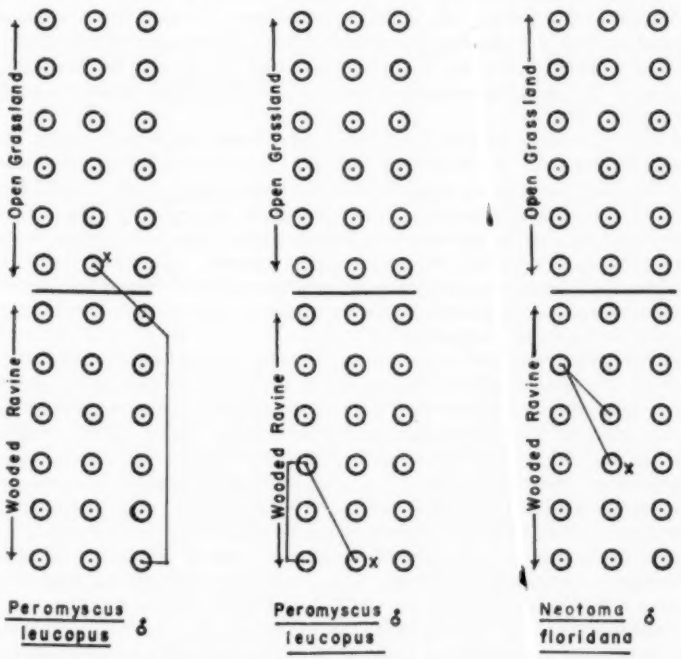

FIG. 3.—Movements of three live-trapped individuals representing the two most abundant species in the wooded ravine. Specimen in the center was immature, others were adults. Symbols as in Fig. 2.

Harvest mice (*Reithrodontomys montanus*) were not thought to be abundant since only six were caught during the entire year. These were taken in two localities in or near grain fields during March. McCarley (1952) found these mice abundant as shown by the capture of 22 mice in 840 trapnights in the tall-grass prairie association in Bryan County, Oklahoma.

The wood mouse (*Peromyscus leucopus*) was the most abundant small mammal in the ravine. Twenty-seven of 36 small mammals taken in 2,615 trapnights of snap trapping in this vegetative type, and 28 of the 45 captures and recaptures in 2,808 trapnights of live trapping, were of this species. Hamilton (1945) pointed out that deer mice are accomplished climbers, a fact verified by several observation of both *Peromyscus maniculatus* and *Peromyscus leucopus* climbing small trees when released from live traps.

The second most abundant small mammal in the ravine was the eastern wood rat (*Neotoma floridana*). Three specimens were taken in snap traps and six caught in live traps. Nests were found along the streams throughout the study area. These rodents usually construct nests in a brush pile, under a fallen tree, or around the base of a tree. Although they are known occasionally to build nests in the branches of a tree, no such nests were observed in this area, where most of the nests were constructed around logs and well covered by green briar (*Smilax Bona-nox*). On one occasion six of these nests were observed while setting 100 traps, within a distance of about a quarter mile, in a ravine near the town of Goldsby.

The pine vole (*Pitymys nemoralis*) is apparently one of the rarest small mammals in the area as only one specimen, caught in high grass along a fence row in the open grassland, was taken in 5,230 trapnights. Although this vole was not taken in the ravine, it is probably present. Schmidt (1931) found it only in the hardwood forest in Clark County, Wisconsin, and stated that no trace of it was found in cultivated fields, pastures or orchards. Blair (1939) found that, in eastern Oklahoma, this species was quite abundant in the floodplain forests. McCarley (1952) reported one specimen from the postoak-blackjack association in 160 trapnights in Bryan County.

The short-tailed shrew (*Blarina brevicauda*) was collected only from the ravine but is undoubtedly present in the grassland area. Burt and Grossenheider (1952) stated that members of the species were found in nearly every available habitat. Pruitt (1953) found this mammal in all habitats investigated in Michigan, even in dry, sandy uplands.

A review of the data on movements of animals in this study substantiates the work of Johnson (1926), Dice (1932) and many other investigators, who found that *Peromyscus maniculatus* lived primarily in open places and that *Peromyscus leucopus* was a forest dweller. The two species meet at the forest edge but each tends to remain in its native habitat, a fact further verified by the snap-trap record.

In this study the number of males captured exceeded the number of females by 18.5 per cent; this is in agreement with the findings of Burt (1940) for the deer mouse, Blair (1940) for the meadow mole, and others. Both workers attributed the greater catch of males to the greater tendency of males to wander. On the other hand, Stickel (1946), working with *Peromyscus leucopus* in Maryland, found that males and females were taken in equal numbers in live traps. However, she found that males outnumbered females two to one in movement toward a central area which had been previously depopulated of this species. The present investigation showed total movement to be approximately the same for males and females.

It seems worthy of mention that of the five different species of rodents—*Perognathus hispidus, Peromyscus maniculatus, P. leucopus, Sigmodon hispidus* and *Neotoma floridana*—which were taken in live traps, the deer mouse and the wood mouse were least shy and usually did not hesitate to enter a trap a second time. This was substantiated by the fact that one *Peromyscus maniculatus* was recaptured 14 times. More than once, after a deer mouse had been released from one trap it was caught in another before the writer left the trapping area. The study of the movements of these mammals further indicated that of the five species involved, all seemed to remain in a definite location which is probably an important factor controlling

or limiting distribution. This supports the evidence of Johnson (1926) on *Peromyscus maniculatus* and *P. leucopus*.

The greater abundance during the summer, which indicated greatest movement of mammals, was closely correlated with the maturing of young mice. Young deer mice usually move away from their birthplace as they mature, apparently because of population pressure (Blair, 1940).

It seems doubtful that any of the small mammals remained in the live-trap area for as long as one year. The trap record showed that five months was the longest period any rodent (a cotton rat) was retrapped in the area, which indicates a very short life span for rodents in this vicinity. These data seem to agree with Burt (1940) who, after two years of live trapping, postulated that *Peromyscus leucopus* died in nature before reaching one year of age, and with Blair (1948) who found that the average life span of *Peromyscus maniculatus, P. leucopus* and *Microtus pennsylvanicus* in nature, as estimated from trap records, was approximately 4½ to 5 months for each species. Both authors attributed the short life span of small mammals in nature to predation. Since skunks, weasels, coyotes, snakes and owls inhabit the study area it would seem a rare phenomenon for a small mammal to die from old age. It was of interest that, after releasing a prairie spotted skunk from a live trap in the open grassland, the remains of a cotton rat were found in the trap. It was evident that the cotton rat had served as bait for the skunk, but this proved of no assistance in the writer's study of movement and distribution of small mammals.

ACKNOWLEDGMENTS

The material reported in this paper is taken from a portion of the author's dissertation for the Ph.D. Degree in the Department of Zoology, University of Oklahoma, Norman. The encouragement and supervision of Dr. A. O. Weese is gratefully acknowledged. I would like to thank Dr. Bryan P. Glass, of Oklahoma State University, for identification of mammals.

SUMMARY

(1) During a one-year study in McClain County, Oklahoma, a total of 233 mammals were collected and catalogued; of these, 184 (79 per cent) were taken from the open grassland and 49 (21 per cent) were taken from the wooded ravine. (2) A greater number of small mammals were found to inhabit the open grassland than the wooded ravine. (3) From the standpoint of numbers collected, *Peromyscus maniculatus, Perognathus hispidus* and *Sigmodon hispidus* were the most abundant small mammals in the open grassland; in the ravine, *Peromyscus leucopus* and *Neotoma floridana* were the most abundant. (4) For determining the most abundant species in the two vegetative types, two methods of trapping, live trapping and snap trapping, were found to be comparable. Approximately three times as many small mammals were taken in the grassland as in the ravine by each method of trapping. (5) Although some mammals moved freely from one vegetative type to the other, most were restricted to only one vegetative type and were seldom found outside their native habitat. (6) More males than females were captured in the live traps; however, the total movement for males and females, as shown by the live-trap record, was approximately the same (7) The number of small mammals captured in traps varied with the seasons of the year.

LITERATURE CITED

BAILEY, V. 1921. Capturing small mammals for study. Jour. Mamm., 2: 63–68.

BLAIR, W. F. 1939. Faunal relationships and geographic distribution of mammals in Oklahoma. Amer. Midl. Nat., 22: 85–133.

———. 1940. Home ranges and populations of the meadow vole in southern Michigan. Jour. Wildl. Mgt., 4: 149–161.

———. 1941. Techniques for the study of mammal populations. Jour. Mamm., 22: 148–157.

———. 1948. Population density, life span, and mortality rates of small mammals in the blue-grass meadow and blue-grass field associations of southern Michigan. Amer. Midl. Nat., 40: 395–419.

Blair, W. F. and T. H. Hubbell. 1938. The biotic districts of Oklahoma. Amer. Midl. Nat., 20: 425–454.

Bruner, W. E. 1931. The vegetation of Oklahoma. Ecol. Monogr., 1: 99–188.

Burt, W. H. 1940. A study of prairie deer mouse populations in southern Michigan. Amer. Midl. Nat., 24: 273– 305.

———. 1940. Territorial behavior and populations of some small mammals in southern Michigan. Misc. Publ. Mus. Zool. Univ. Mich. No. 45: 1–58.

——— and R. P. Grossenheider. 1952. A field guide to the mammals. Houghton Mifflin Co., Boston.

Carpenter, J. R. 1939. The grasslands biome. Amer. Midl. Nat., 21: 75–91.

Dice, L. R. 1932. The prairie deer-mouse. Cranbrook Inst. Sci., Bull. 2.

———. 1943. The biotic provinces of North America. Univ. Mich. Press, Ann Arbor.

Goodnight, C. J. and E. J. Koestner. 1942. Comparison of trapping methods in an Illinois prairie. Jour. Mamm., 23: 435–438.

Gray, J. A., Jr. 1943. Rodent populations in the sagebrush desert of the Yakima Valley, Washington. Jour. Mamm., 24: 191–193.

Hamilton, W. J., Jr. 1942. Winter reduction of small mammal populations and its probable significance. Amer. Nat., 76: 216–218.

———and D. B. Cook. 1945. Small mammals and the forest. Trans. N.A. Wildl. Conf., 10: 137–139.

Johnson, B. W. 1927. Preliminary studies of mice of Mount Desert Island, Maine. Jour. Mamm., 8: 276–284.

Johnson, M. S. 1926. Activity and distribution of certain wild mice in relation to biotic communities. Jour. Mamm., 7: 245–284.

Kelting, R. W. 1954. Effects of modern grazing on the composition and plant production of a native tall-grass prairie in central Oklahoma. Ecology, 35: 200–207.

McCarley, W. H. 1952. The ecological relationships of the mammals of Bryan County, Oklahoma. Texas Jour. Sci., 1: 102–112.

Phillips, P. 1936. The distribution of rodents in overgrazed and normal grasslands of central Oklahoma. Ecology, 17: 367–379.

Pruitt, W. O., Jr. 1953. An analysis of some physical factors affecting the local distribution of the shorttail shrew (*Blarina brevicauda*) in the northern part of the lower peninsula of Michigan. Misc. Publ. Mus. Zool. Univ. Mich., No. 79, 39 pp.

Schmidt, F. J. W. 1931. Mammals of western Clark County, Wisconsin. Jour. Mamm., 12: 99–117.

Stickel, L. F. 1946. The sources of animals moving into a depopulated area. Jour. Mamm., 27: 301–307.

———. 1946. Experimental analysis of methods for measuring small mammal populations. Jour. Wildl. Mgt., 10: 150–159.

Taylor, W. P. 1930. Methods of determining rodent pressure on the range. Ecology, 11: 523–542.

U.S. Dept. Comm. 1952. Climatological data for Oklahoma, 61: 180–191.

———. 1953. Climatological data for Oklahoma, 62: 1–128.

Weaver, J. E. and F. E. Clements. 1938. Plant ecology. McGraw-Hill Book Co., New York.

Welch, P. L. 1929. A reconnaissance of a typical Oklahoma prairie. Unpublished M.S. dissertation, Univ. of Okla.

Dept. of Biology, Kansas State Teachers College, Pittsburg. *Received September 12, 1956.*

A NEW WEASEL FROM THE LOWER PLEISTOCENE OF IDAHO

By Claude W. Hibbard

This is one of a series of papers on the later Cenozoic fossils from the Snake River Valley area in cooperation with Dwight W. Taylor, of the United States Geological Survey. Taylor has found numerous remains of small vertebrates associated with mollusk shells in the area under study. Among the fossil mammal remains is the lower jaw of an extinct weasel which is described as new.

Mustela gazini sp. nov.
(Figs. 1*A–B*)

Holotype.—No. 21824, U.S. National Museum, part of a left lower jaw bearing P_3–M_2, alveoli of P_2 and the alveolus of the canine. Collected in the summer of 1955 by Dwight W. Taylor of the U.S. Geological Survey.

Horizon and type locality.—Lower Pleistocene (Aftonian?) Hagerman formation; Hagerman local fauna. Locality No. 540 D.W.T., Hagerman quadrangle, SW¼ Sec. 28, T. 7 S, R. 13 E, 2,100 feet north and 300 to 400 feet east of southwest corner; elevation 3,025 feet; Twin Falls County, Idaho.

Diagnosis.—A weasel the size of a male *Mustela frenata nevadensis* Hall. It is distinguished from *Mustela frenata* by a lesser transverse width of the heel of P_4 and P_3. The principal cusp of P_4 and P_3 of the fossil form is more centrally located than in *M. frenata*. The anterior part of P_4 and P_3 of *Mustela gazini* is not as reduced as in the Recent weasels.

Description of holotype.—The distance from the posterior border of the canine alveolus to posterior border of the alveolus of M_2 is 13.8 mm. The anteroposterior length of P_3–M_2 is 11.6 mm. P_2 had two well-developed roots. P_3 resembles P_4 in shape but is smaller (Fig. 1*B*). The principal cusp of P_3 is located more posteriorly than in Mustela frenata. In the Recent species it is located more anteriorly and is almost directly over the anterior root of P_3. The heel of P_4 is not expanded transversely where it leaves the base of the cusp. The lingual basin (valley) separating the paraconid and protoconid blades is deeper than in *M. frenata*. The carnassial notch of M_1 is closed. The anteroposterior length of M_1 is 5.75 mm. The greatest transverse width of M_1 is

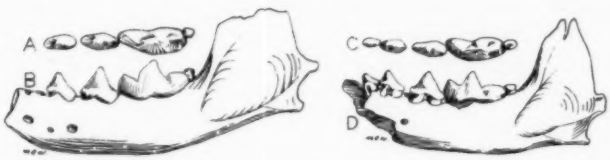

Fig. 1.—*A* and *B*, *Mustela gazini* sp. nov. (*A*) Occlusal view of $LP_3 - M_2$, holotype; (*B*) lateral view of left lower jaw, holotype, U.S.N.M., No. 21824. *C* and *D*, *Mustela rexroadensis*. (*C*) Occlusal view of $LP_2 - M_2$; (*D*) lateral view of left lower jaw, topotype, U.M.M.P., No. 30243. All × 2. Drawn by Michael O. Woodburne.

2.1 mm. The greatest transverse width of M_2 is 1.0 mm. This species is named for C. Lewis Gazin.

Remarks.—Mustela gazini is distinguished from *M. rexroadensis* Hibbard (Fig. 1*C–D*) by its larger size and by the better developed anterior base of both P_3 and P_4. The carnassial notch is not as tightly closed in *M. rexroadensis.* For a list of the Hagerman fauna see C. Lewis Gazin, Proc. U.S. Nat. Mus., 83(2985):285, 1936.

Remains of *Mimomys* (*Cosomys*) *primus* (Wilson), *Pliopotamys minor* (Wilson) and *Blarina gidleyi* Gazin, were found in association with the weasel jaw.

Museum of Paleontology, Univ. of Michigan, Ann Arbor. Received May 17, 1957.

PELAGE STAGES IN THE COTTONTAIL RABBIT

By Norman C. Negus

A number of criteria have been employed to determine the age of cottontail rabbits. These include weight measurements, total length measurements, condition of the hymen in females, size of male genitalia, and ossification of epiphyseal cartilage in the bones of the forefeet. Having undertaken a study of reproduction in the cottontail rabbit, *Sylvilagus floridanus mearnsi,* in Ohio in 1952, I was faced with the problem of accurately aging rabbits in the field. The above methods had the disadvantage of either being impractical for field use or of not being useful in accurately aging young rabbits late in the breeding season.

This study was made possible through financial assistance from the Ohio Cooperative Wildlife Research Unit and a grant from the Wildlife Management Institute. For cooperation and assistance during the study I am greatly indebted to many of the faculty and graduate students in zoology at Ohio State University, and to personnel of the Ohio Division of Wildlife, whose names are too numerous to mention here. In particular I should like to acknowledge the invaluable advice and criticism afforded me throughout the study by Dr. Eugene H. Dustman, Leader of the Research Unit. A portion of these data was presented at the 16th Midwest Wildlife Conference.

The pelage stages of cottontails have not been adequately described. Nelson (1909) recognized three distinct pelage stages apparently common to all North American hares and rabbits. These were designated as *juvenal, postjuvenal* and *adult* pelage. He described *Sylvilagus* as a genus having only one annual molt. He did recognize that species in the genus *Lepus* and subgenus *Brachylagus* experienced two molts annually. Dalke *et al.* (1942) concluded that adult cottontails experienced a continual molt over a nine-month period, from March to November.

Three constituents of the dorsal pelage of cottontail rabbits have been described by Nelson: (1) a fine short underfur, usually buffy or gray; (2) a longer, thinner, coarser coat of hairs, dusky at the tips, with a broad subterminal

zone of buffy or grayish; (3) an even longer, coarser, sparser set of hairs, glossy and blackish in their terminal half.

METHODS

During preliminary fieldwork in 1952, I first noticed that there were markedly different pelage stages in the cottontail rabbit. As more specimens were examined a definite relationship of age to pelage became apparent. In 1953 and 1954, many data on pelage were gathered concurrently with other fieldwork. Notes on the nature of the pelage and molting characteristics were recorded for every rabbit trapped immediately upon withdrawing an animal from a trap, before either weight or reproductive data were recorded. Subsequent to recording the pelage data, the sex was determined as well as the weight to the nearest half ounce. The rabbit was then either released or killed for examination of the reproductive tract. A forefoot was saved from all rabbits killed for examination. These were ultimately photographed with an X-ray camera in the laboratory to substantiate pelage-age determinations by ascertaining the degree of ossification at the proximal end of the humerus and the distal ends of the radius and ulna. The results reported here are based upon several hundred pelage observations made between 1952 and 1955.

RESULTS AND DISCUSSION

Three pelage stages were discernible in young cottontail rabbits. These I have designated as *nestling fur, juvenal pelage,* and *subadult pelage.* Two molting phases appeared definitely related to age: (1) the molt from nestling fur to juvenal pelage; (2) the molt from juvenal to subadult pelage. Once it had become obvious that pelage stages were typical of specific weight ranges, each pelage observation was assigned an age approximation on the basis of the weight of the animal compared to an age-weight curve derived by Petrides (1948) from known-age cottontails. As a result the following pelage stages appear to occur consistently in specific age groups:

Nestling fur.—Age range, 2.0–5.5 weeks. Weight range, 4.0–8.5 ounces. This fur is characterized by its fine downy texture, its dense nature and rather gray coloration.

Molt to juvenal pelage.—Age range, 5.5–7.0 weeks. Weight range, 8.5–10.0 ounces. This molt occurs in a sheet pattern growing in through the nestling fur.

Juvenal pelage.—Age range, 7.5–10.5 weeks. Weight range, 10.5–17.5 ounces. This stage is characterized by the thinness of the pelage, salt and pepper appearance, and generally dark coloration.

Molt to subadult.—Age range, 11.0–14.5 weeks. Weight range, 18–27 ounces. Molt occurs in a sheet pattern beginning on the rump and sides.

Subadult pelage.—Age range, 15–30+ weeks. Weight range, 28–44+ ounces. This pelage is characterized by a lighter buffy coloration as a whole than the adult summer pelage, lighter gray coloration of the underfur, and a general salt and pepper appearance caused by sparseness of dark outer long hairs.

The *adult summer pelage* is characterized by over-all darker brown coloration than subadult pelage, darker coloration of the underfur, and general glossy appearance due to greater density of long hairs. Figure 1 indicates the relationship of pelage stages to age and weight.

The persistence of tufts of lighter colored winter guard hairs late into the summer in adult rabbits aids in distinguishing adult summer pelage from subadult pelage. This is particularly useful in adults that possess a lighter than average pelage coloration. The molt from winter to summer pelage in adult cottontails occurs in a mottled molt pattern over the dorsal and lateral regions of the body. This has been observed by Dalke (*op. cit.*), and is in contrast to the sheet pattern of molting in immature rabbits.

Aging by pelage criteria is successful up to the time of the fall molt to winter pelage. This begins sometime in September in Ohio, when all animals regardless of age appear to molt into what might be called adult winter pelage. In this pelage the various age groups are indistinguishable from each other by pelage characteristics. Rabbits in juvenal pelage at the time of the fall molt appear to omit the subadult pelage stage, and molt directly into winter pelage. Morejohn and Howard (1956) have suggested that this may occur in young pocket gophers (*Thomomys*) in California.

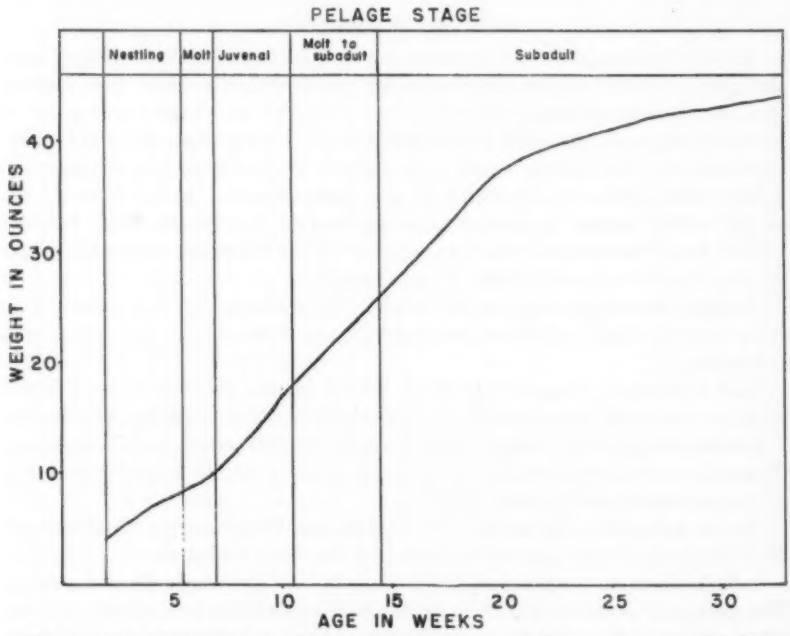

FIG. 1.—The relationship of pelage stages to age and weight in young cottontail rabbits. The growth curve is adapted from Petrides (1948).

Aging by pelage criteria is particularly useful in distinguishing subadults from adult rabbits in the field. Many of the young from first and second litters of the season attain adult proportions before the end of the summer, and hence would be classed as adults by weight and measurement data. I have found that almost 50 per cent of first and second-litter young become sexually active in their first summer. Characteristics of the genitalia and teat size would classify sexually active young rabbits as adults—perhaps one reason why there are so few published records of young rabbits attaining sexual maturity in their first summer.

I cannot agree with the views of Nelson that *Sylvilagus* is a genus having only one annual molt, or with Spinner (1940) that a continuous molt occurs from March to November. The spring molt from winter to summer pelage is a gradual process extending over a period of about five months. However, I have examined adult rabbits, particularly in August, which were in complete summer pelage and bore no external indications of new hair growth. The period of complete summer pelage is admittedly of very short duration, but it indicates that there are two distinct molts in *Sylvilagus*, one of long duration (spring) and the other of rather short duration (fall). Morejohn and Howard (*op. cit.*) noted in pocket gophers that the molt to summer pelage was of distinctly longer duration than the fall molt, and that complete summer pelage apparently seldom occurred. Data from the present study indicate that this is also true of *Sylvilagus* in Ohio.

The causes of molting have not been thoroughly investigated. Hammond (1925) suggested a relationship between reproductive function and molting. Hadwen (1929), after maintaining captive hares in heated rooms over an extended period, decided that environmental factors were not the causes of molting sequences. Spinner (1940) found an apparent relationship between the weight of the testes in adult male cottontails and the onset of molting. Testes began to gain weight during the non-molting period in December and lost weight at the beginning of the molting period in the spring. He also found that testicular weight decreased markedly with the onset of molting in September. He noted that pregnant females captured from September to November had a mottled molt pattern, while non-pregnant females taken during the same period usually exhibited a sheet molting pattern.

Information on molting during the present study indicates a rather close relationship to reproductive activity. In adults collected in April, which were pregnant with their first litters of the season, the molt to summer pelage had just begun in the head region, particularly around the eyes. Adult females collected in April that had more advanced embryos of either first or second litters were generally more advanced in the stage of molting from winter to summer pelage. This was true of rabbits examined from both eastern and western Ohio. Specimens collected in May were characterized by a profuse growth of summer pelage over the body, and persistence of patches of winter pelage in the dorsal region. As the breeding season progressed there appeared

to be less correlation of pelage stage with reproductive activity, suggesting that the influence of reproductive activity on molting is not the only factor involved.

The earliest complete adult summer pelage was noted in an adult female collected on June 4, 1954, in Marion County. At the time of collection this rabbit was recorded in complete summer pelage. Subsequent examination of the uterus and ovaries revealed that she was well along in her third pregnancy, far advanced so far as number of litters is concerned at that time of the breeding season. Not until the end of July were more fully adult females observed in complete summer pelage.

Molting of adult males seems to follow approximately the same sequence as that of the females except that the molt to summer appeared to progress more rapidly after the end of May. Molting was observed to have just begun in April, and was progressing over the dorsal region at least through May. Mottled molt patterns persisted through the month of June. From about July 10 to the end of the month males were in summer pelage with only a few traces of winter pelage persisting in most animals.

Initially, there appeared to be a large amount of individual variation in the time of molt of adult cottontails. However, after further laboratory analysis of the reproductive tracts of specimens collected, greater consistency was evident than I formerly supposed, at least in relation to reproductive activity. For example, an adult female from Knox County collected on May 21, 1954, was still in complete winter pelage with no sign of molting to summer pelage. This rabbit was found to be pregnant with her first litter of the season, and thus had begun breeding later than the average cottontail in 1954. An adult male trapped in Muskingum County, in June, was observed to have partially undergone the molt to summer pelage at the time of his capture. He was retained in a hutch outdoors and examined periodically throughout the summer. The molt to summer pelage was not completed but remained in much the same condition as when the rabbit was trapped, with a large area of winter pelage persisting dorsally and laterally. Periodic examinations revealed that the testes of this male remained about 20 mm. in length and at no time were they observed to be fully descended and enlarged. It seems likely that the failure to complete the molt to summer pelage in this case was related to the reproductive condition of the animal.

On the basis of 76 pelage observations in the fall of 1953 and 1954, it appeared that the molt to winter pelage in adults and young began during the first ten days of September. These observations agree rather well with those made by Dalke *et al.* in regard to fall molting. Again in adults, this was subject to variation related to the stage of the reproductive cycle of each specimen. Thus, an adult female captured on September 28, 1953, at the Olentangy Wildlife Experiment Station, Marion County, was pregnant with five embryos which were aborted several days later in captivity. This rabbit had not begun the molt to winter pelage. An adult female caught on the same

TABLE 1.—*Pelage stages and reproductive data from a sample of adult female cottontail rabbits in 1954*

DATE	REPRODUCTIVE DATA	CROWN-RUMP MEAS., *mm.*	PELAGE STAGE
4-22	Pregnant (2nd litter)	16.5	Winter, molting slightly
4-23	Pregnant (2nd litter)	Minute	Winter, molting on face
4-23	Pregnant (2nd litter)	Minute	Winter, molting on face
4-23	Pregnant (2nd litter)	Minute	Winter, molting on rump and back
4-24	Pregnant (2nd litter)	5.0	Winter, molting slightly
4-24	Pregnant (2nd litter)	3.9	Winter, molting dorsally
4-24	Pregnant (2nd litter)	4.0	Winter, molting dorsally
5-8	Pregnant (1st litter)	95.0	Winter, molting in small patches dorsally
5-8	Not preg. (had 1 lit.)	....	Winter, molting dorsally
5-10	Pregnant (3rd litter)	Minute	Mottled molt pattern dorsally
5-21	Pregnant (1st litter)	Minute	Winter, no visible molt
5-23	Pregnant (2nd litter)	12.3	Summer complete dorsally
5-25	Pregnant (2nd litter)	33.5	Summer growing in dorsally
5-29	Pregnant (1st litter)	37.8	Winter shedding, summer growing in dorsally and laterally
5-30	Pregnant (2nd litter)	35.0	Summer growing in through remnant of winter
6-3	Not preg. (had 2 lit.)	....	Summer almost complete; winter tufts persisting
6-4	Pregnant (3rd litter)	45.7	Summer pelage complete
6-11	Not preg. (had 2 lit.)	....	Molting to summer dorsally
6-14	Not preg. (had 2 lit.)	....	Summer complete dorsally, incomplete laterally
6-14	Pregnant (2nd litter)	Minute	Summer almost complete dorsally
6-14	Pregnant (2nd litter)	6.3	Mottled molt to summer
6-16	Pregnant (3rd litter)	2.5	Summer almost complete
6-16	Pregnant (2nd litter)	9.8	Summer almost complete
6-16	Not preg. (had 1 lit.)	....	Summer almost complete
7-10	Pregnant (2nd litter)	Minute	Mottled molt to summer
7-30	Not preg. (had 2 lit.)	....	Summer complete except for winter tufts
7-31	Pregnant (2nd litter)	Minute	Summer complete except for winter tufts
7-31	Pregnant (4th litter)	74.7	Summer pelage complete
7-31	Pregnant (3rd litter)	68.4	Summer complete except for winter tufts
8-23	Not preg. (had 3 lit.)	....	Summer pelage complete
9-18	Not preg. (had 2 lit.)	....	Summer, molting all over to winter
10-26	Not preg. (had 3 lit.)	....	Winter growing in, on rump particularly
10-26	Not preg.	....	Winter pelage complete
11-1	Not preg. (had 4 lit.)	....	Winter pelage growing in
11-11	Not preg.	....	Winter pelage complete

day with enlarged teats but not lactating or pregnant (i.e., having had her last litter of the season) was molting profusely to winter pelage. Five other adult females caught within three days of this date had ceased breeding for the year and were in various stages of molting to winter pelage.

The fall molt occurs in more of a sheet pattern than the spring molt, usually beginning in the region of the rump and sides, and progressing dorsally. Most of the adults examined attained full winter pelage by the third or fourth week of October. In all cases observed, winter pelage was complete by the first week of November. Table 1 summarizes the observational data on pelage as well as the reproductive data from a sample of adult females killed in 1954.

A relationship between pelage sequences and reproductive function undoubtedly exists in other species of mammals. My own recent studies of *Microtus richardsoni macropus* in Wyoming indicate a close correlation between aquisition of subadult pelage and attainment of sexual maturity. A more detailed study of pelage in relation to reproductive activity than was undertaken in the present study may clarify the causal nature of this relationship.

SUMMARY

Pelage stages in the cottontail rabbit in Ohio were found to be closely related to age and reproductive activity. In young rabbits pelage stages indicative of specific age groups are described. These are designated as nestling fur, molt to juvenal pelage, juvenal pelage, molt to subadult pelage, and subadult pelage. Two distinct molts occur in adult cottontails contrary to reports that a single continuous molt occurs. The onset of adult molting appears related to reproductive activity. The relationship of pelage stages to reproductive activity in young and adult rabbits is discussed.

LITERATURE CITED

Dalke, Paul D. *et al.* 1942. The cottontail rabbits in Connecticut. A report on the work of the Connecticut Wildlife Research Unit. Conn. Pub. Doc. 47, 93 pp.

Hadwen, Seymour. 1929. Color changes in *Lepus americanus* and other animals. Canad. Jour. Res., 1: 189–200.

Hammond, John. 1925. Reproduction in the rabbit. Oliver and Boyd, Edinburgh, 210 pp.

Morejohn, G. Victor and Walter E. Howard. 1956. Molt in the pocket gopher, *Thomomys bottae*. Jour. Mamm., 37: 201–213.

Nelson, E. W. 1909. The rabbits of North America. N.A. Fauna No. 29: 1–314.

Petrides, George A. 1948. Sex and age ratios; their determination and uses in game and fur animals of the eastern United States. Ph.D. thesis, Ohio State Univ.

Spinner, George P. 1940. Molting characteristics in the eastern cottontail rabbits. Jour. Mamm., 21: 429–434.

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POPULATION TURNOVER IN WINTERING BATS IN INDIANA

By Russell E. Mumford

The turnover in winter cave bat populations has not been adequately studied, although bat banders (Beer, 1955; Rysgaard, 1942; Griffin, 1940; Guthrie, 1933) are aware that hibernating concentrations do not remain constant throughout any given season. The extent to which the animals move in and out of their hibernating quarters poses an interesting problem. Such shifting is important in evaluating winter populations, banding returns, and perhaps sex ratios (one sex may tend to shift about more than the other). If it can be demonstrated that wintering populations fluctuate from day to day, or week to week, some of the seemingly low rates of band returns may be explained. It is conceivable that the wintering population, though remaining relatively constant with regard to total numbers, may actually be composed of an ever-changing group of individuals. Unless the bats are banded, such population turnovers go undetected.

As Beer (1955) has pointed out, bats are often retaken two or more years after banding, but not *each* successive year. This seems to indicate that they do not utilize the same wintering quarters year after year. It could also mean that, if the premise of constant turnover is true, some banded individuals are simply missed unless the cave is checked frequently throughout the winter season. Bats may utilize two or more suitable hibernacula, shifting from one to the other as natural movement, to facilitate mating, or in response to fluctuating changes in temperature. The big brown bat (*Eptesicus fuscus*), which is known to be quite a hardy species, seems well fitted to winter movements of these types.

I initiated an intensive study on August 7, 1954, and carried it through April 28, 1955, in a natural limestone cave four miles from the center of Bedford, Lawrence County, Indiana. This cavern has been known as Donnehue's Cave for at least 60 years (Blatchley, 1897) and, like many of the numerous caves in this general region, it has a stream of water flowing throughout its length. The entrance is at the base of a small limestone escarpment overlooking the east fork of the White River; it faces south-southeast and is about 30 feet wide by 8 feet high at the highest point. Within the first 364 feet, the cave passage makes seven turns (Fig. 1). This section was considered the best one in which to prosecute the work, since it has relatively smooth walls and ceiling and varies in height from about 6 to 10 feet (average 7). At one place, however, a narrow crevice in the ceiling extends upward to about 14 feet. The width of this passage averages about 8 feet. At the 364-foot mark, the passage forks. One part of this fork is on a higher level, thus is a "dry" one, which circles back to the main, "wet" portion in a short distance. At a point 565 feet from the entrance, the cave opens into a high-ceilinged and relatively large section. This part finally terminates about 1,000 feet from the cave mouth. I had previously banded some *Eptesicus* in this cave in January and March, 1954.

The 76 trips to the cave during the period of study were distributed by months

as follows: August, 13; September, 14; October, 10; November, 9; December, 4; January, 2; February, 6; March, 12; April, 4. I negotiated the entire length of the cave only five times. This was partly because of the dangers of reaching the back portions alone (I was accompanied on only six trips) and the fact that in previous bat banding it has been noted that *Eptesicus* characteristically spent the winter near the cave entrances. Only two *Eptesicus* were observed beyond the 364-foot mark; one of these was just beyond the forks. Thus, in considering the movements to be mentioned later, it appears that the absence of marked individuals from the section of the cave checked each trip was not due to their moving farther back. As visits were made when spare time permitted, they could not be standardized with regard to time of day (or night) or a set frequency. Admittedly, it would have been desirable to check the cave more often, especially through December, January and February.

On almost every trip, all of the bats that could be obtained were removed, banded, and sexed, then usually released immediately at the cave entrance or at a point farther inside the cave. On a few trips bats were counted but not removed from their retreats. Weights were taken of 87 individual *Eptesicus* handled between November 7 and March 8. A sketch map of the cave was prepared and utilized on each trip to record the positions of all bats observed. Bats that could not be extracted from crevices were examined for bands and counted as accurately as possible. With the exception of a very few spots, all of the bats present could be readily observed. It is estimated that over 95 per cent were located on each visit.

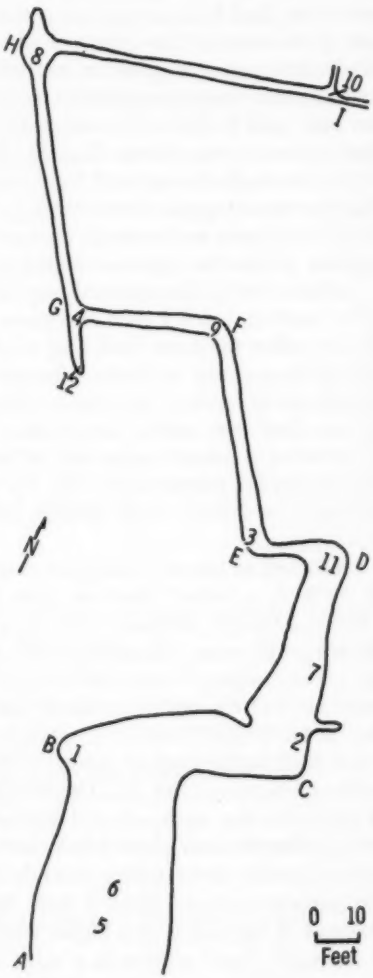

FIG. 1.—Sketch map of Donnehue's Cave, Lawrence County, Indiana, showing temperature stations (numerals) and sections of the cave (letters).

Temperatures were not constant throughout the period in the portions of the cave where most of the bats chose to hang. One site (*E*) varied from 32°F. on January 29 to 45°F. on February 16. At a point farther from the entrance (*G*) variations from 44° to 51°F. were recorded, between February 7 and March 16. Temperatures taken at ten stations throughout the first 364 feet of the cave on February 7 ranged from 35° F., just inside the entrance, to 48°F. (at *B*). The average temperature for these stations was 42.7°.

Water levels fluctuated in the cave as a result of increased drainage following rains, and the increased volume of water no doubt affected temperature changes. Air currents were very noticeable at certain sites (*G* and *I*). It is possible that some small openings to the ground above were present that allowed the passage of air through the cave. Although the strength of these currents was not measured, they were often sufficient to be felt strongly on one's face. What effect water levels, air currents, and resulting temperature and humidity changes may have had on bat movements is not known.

I wish to thank the following persons who assisted me on one or more trips: Ted Brown, Merrill Carrigan, James B. Cope, Cameron Gifford, Earl George, Ralph Kirkpatrick, Jay Schnell, Susan Smith, Dr. William Stephenson, and Gertrude Ward. I also would like to acknowledge the many helpful suggestions given by Dr. William H. Burt, who read the manuscript.

Population.—All bats observed each trip were recorded, whether they could be captured and examined or not. It soon became evident that the population exhibited fluctuations from day to day and the subsequent checking of banded individuals permitted some analysis of these trends. Bats handled the previous day might be absent, and unbanded ones present in sites known to have been unoccupied the previous visit.

The average number of *Eptesicus* observed each trip was 6.8, but on 28 of the 76 visits none was found. It was definitely established by banding that at least 109 individual *Eptesicus* utilized the cave on one or more days between August 7 and March 27. Yet, the maximum noted on any one visit was 39 (36.1 per cent) on February 17. Other days which resulted in counts of over 30 were: December 3 (32); December 29 (33); January 7 (34); January 12 (33); January 16 (34).

Climatological data from the weather station at Bedford during the period of study were analyzed for any correlation with the daily *Eptesicus* population. The first date on which the temperature fell below freezing in the fall of 1954 was October 18, when the minimum was 31°F. However, 21 days in October had minima above 32°F., while November had 14, December 8, January 5, February 7, and March 14 days with minima above 32°F. Practically all of the *Eptesicus* had left the cave by April 1. In the 164-day period from October 18 to April 1 there were 52 days on which the minima exceeded freezing. Theoretically, it was then possible for *Eptesicus* to remain out of the cave much (31.7 per cent) of the hibernating period without being subjected to temperatures below freezing. There were 24 periods ranging from 1 to 22 days from

October 18 to April 1 when the minimum temperature was 32°F. or below. Aside from a 22-day period from January 10 to 31 and a 14-day period from February 2 to 15, bats were required to remain in the cave to escape freezing temperatures for only very brief intervals throughout the winter. It is also quite possible that the bats were able to withstand temperatures at or slightly below freezing or that they sought refuge in other shelters instead of returning to the cave. This would allow them to change their roosts almost at will.

It was noted, however, that a rather high correlation existed between the number of individuals observed on each trip and the minimum temperature for that particular day. Thus, as one might suspect, it appeared that movements in and out of the cave were, at least partially, in response to external temperature. The minimum temperatures on the days when more than 30 bats were observed (as given previously) were 28, 27, 33, 20, 23, and 19, respectively.

I removed 15 *Eptesicus* from the cave on February 28 and released them in the center of Bedford (4 miles away) about 5:30 PM the same day. On my next visit to the cave, March 1, I found 13 fewer *Eptesicus* than on February 28, but the temperature minimum had been above 40°F. for the intervening time. Thus, part of the population may have left the cave voluntarily as the weather moderated. Two of the bats liberated in Bedford on February 28 were recaptured in the cave, one each on March 2 and 22. The temperature minima for these days were 27°F. and 23°F., respectively. The population dropped to a single *Eptesicus* on March 15 and 16. Seven were present March 27, a day with a minimum temperature of 10°F. (the minimum for March 26 was 6°F.). By March 31, the low temperature was 33° and only one *Eptesicus* was present. This was the last one found in the cave to April 28, when I last visited it. Further discussion of population fluctuation is presented under "Movements."

It is readily seen that a single visit, or perhaps two, would not have given an accurate picture of the wintering population. A check of the cave on any one day between December 1 and March 1, for example, would have revealed a maximum of 16 to 39 *Eptesicus*, as compared with the known number of 109 bats of this species that actually utilized the cave. If this type of behavior were encountered in large concentrations, an erroneous impression would be obtained with regard to sex ratios, winter population, and band recoveries. Therefore, trips taken to caves under study must be planned periodically throughout the hibernating season in the latitude of Bedford, Indiana. To what extent such movements occur in more northern areas remains to be worked out. Since it is often impractical to make repeated observations on a cavern under study, the visits should be made after several days, or weeks, of sufficiently cold weather to force more of the animals back into the cave. Again, this depends upon the latitude of the area under study. From my data, it appears that a temperature of about 30°F. is sufficient to cause some of the bats to move back into their winter retreats. However, we do not know as yet the exact temperature tolerance of *Eptesicus*.

Sex ratios.—The 76 *Eptesicus* banded for the first time during the study

period consisted of 40 males, 34 females, and 2 unsexed individuals. This is a ratio of 54 per cent males, disregarding the two individuals for which sex was unrecorded. The 64 *Eptesicus* banded in this cave in January and March, 1954, exhibited a 50:50 sex ratio. Eighteen of the 32 males and 13 of the 32 females banded in the spring of 1954 were recaptured during the winter of 1954–55.

Considering all of the *Eptesicus* known to have utilized the cave in 1954–55, I found that 55.1 per cent of the total of 107 (disregarding the two unsexed) were males. This is not a serious discrepancy in the sex ratio, although others (Beer, 1955; Mohr, 1945; Hitchcock, 1949; Rysgaard, 1942) have reported from 32 to 78.6 per cent males in wintering populations of *Eptesicus*.

Movements.—The foregoing discussion of population has brought out the fact that considerable movement occurred among the wintering group of bats. The following data will treat these movements in more detail, thus providing a better picture of the nature and extent of population fluctuations.

The 76 *Eptesicus* banded for the first time during the study period entered the cave as follows: August, 5; September, 1; October, 1; November, 23; December, 27; January, 11; February, 6; and March, 2. The 31 returning from bandings in the spring of 1954 were captured as follows: August, 1; September,, 1; October, 2; November, 15; December, 3; January, 5; February, 3; March, 1. It is readily seen that most of the influx occurred in November and December, but that the animals were entering the cave during eight of the nine months under observation. Even though the influence of my activities on initiating movements out of the cave cannot be evaluated, this pattern of influx seems pertinent. It seems logical to assume that since there was this influx throughout the season, the likelihood of egress from the cave was equally probable. As the next section will show, egress and ingress were both common occurrences, as revealed by data regarding the number of times individuals were recaptured. I detected no difference between males and females in this behavior.

Two interesting band returns were reported to the U.S. Fish and Wildlife Service during the study. One, a female *Eptesicus*, banded in Donnehue's Cave January 9, 1954, was killed in a barn 6 miles south of Sullivan, Indiana, on April 16, 1955. This is an airline distance (WNW) of about 52 miles. The other, a male *Eptesicus*, also banded in the cave January 9, 1954, was found alive on the ground beneath a coal-loading tipple near Elkton, Kentucky, on December 31, 1954. This is an airline distance (SSW) of about 142 miles. Neither of these bats had been recaptured in the cave before final recovery.

Although a colony of *Eptesicus* was located in a building in Bedford, 4 miles from the cave, I found no indication of interchange of bats between these two sites. I banded 41 males and 48 females from this building on August 30, 1954.

Frequency of recaptures.—There was wide variation in the number of times any particular individual was captured after banding. Altogether 40 (21 males

and 19 females) of the 76 *Eptesicus* banded from August to April were retaken. Twenty of these were recaptured only once; 12 twice; 4 three times; 2 four times; and 2 six times. Each was thus recaptured an average of 1.9 times. Among this group, the period of time between recaptures varied from 2 to 193 days; average, 36.2. Five of these intervals were over 100 days. Band No. 49-180112, for example, was retaken six times, at intervals of 67, 12, 19, 11, 22, and 5 days. Another individual (No. 49-181027), also recaptured six times, appeared at intervals of 11, 41, 123, 38, 14, and 5 days. It would be interesting to know where these bats resided when absent from the cave.

The 31 *Eptesicus* returning to the cave from previous bandings in the spring of 1954 exhibited similar behavior. Fourteen of these were located only once; 9 twice; 2 three times; 1 four times; 1 six times; 3 seven times; and 1 eight times, for an average of 2.7 times each. The interval between recaptures ranged from 2 to 141 days; average, 28.0.

An analysis of the histories of the five bats banded in August may prove of interest. Four of these were subsequently taken in the cave during the study period, on August 18, September 6 and 29, and March 1, respectively. Female No. 49-181031, banded on August 20, did not return to the cave until March 1. This may indicate that she stopped off in the cave in August en route to another wintering site, then reentered the cave in March en route to a summer range. One of the remaining three (all males) was banded August 7, recaptured six times by March 27, but was absent from the cave for a period of 123 days between September 28 and January 29. A male banded August 18 was last captured October 4, while the remaining male, banded August 19, was not found after September 6. Another male banded September 28 was first recaptured January 7. These records seem to strengthen the possibility that the first bats to enter the cave in the fall, in this case August and September, may be transients. There was also an indication that *Eptesicus* entering the cave in January, February, and March were more or less transient individuals. Of 11 banded in January, only four were retaken, while none of the eight banded in February and March was recaptured. In contrast, 14 of the 23 banded in November and 16 of the 27 banded in December were subsequently captured. These data support the earlier population figures in regard to the probability that the winter congregations tend to be most stabilized in November and December. Perhaps more detailed investigations of various (and larger) colonies will shed more light on this phenomenon.

Roosting habits.—Although some bats were found hanging in exposed sites on the side walls or ceiling, most seemed to prefer a more sheltered spot. The walls and ceiling of Donnehue's Cave contained many areas where "flakes" of limestone had become loose and pulled away from the wall, forming tiny crevices. Many utilized such recesses; the number of bats in a group was often in proportion to the length of the crevice. Both vertical and horizontal fissures were favored roosting sites. It was not unusual to find several bats tightly packed into a horizontal crack in such a manner that one or more of the

bats was lying on its back. Small, circular holes in the ceiling often sheltered one or two bats, as did the "folds" and hollow cores of large, broken stalactites. All of the *Eptesicus* noted were hanging high enough above the water to escape flooding after heavy rains.

Records were maintained on each trip of the group sizes encountered. When practical, the sex ratios of these groups were determined. It was often necessary to record single individuals or groups as unsexed, since they could not be extracted from their retreats. These data involved observations on 496 *Eptesicus*, many of which were counted more than once. In compiling the sex ratios for singles and groups, all of the bats noted on all trips were included. A total of 309 animals were found hanging singly; 84 were males, 88 were females, and 137 were not sexed. The remaining 142 noted were arranged in groups containing from 2 to 10 bats. There were 29 groups of two, 7 of three, 6 of four, 1 of five, 2 of six, 5 of seven, 2 of eight, and 2 of ten. Five of the groups of two consisted of one male and one female; in two such groups both were males and in two groups both were females. Only 45 (28 males and 17 females) of the bats occurring in groups could be sexed. All of the gatherings containing over four animals were in situations from which they could not be removed without injuring them.

Work in other Indiana caves has resulted in meager information on the sex ratios of hibernating clusters of *Eptesicus*. I found at least 40 in a tightly packed fissure in a Jefferson County cave on January 6, 1954. The 18 that could be extracted were all males. On February 20, 1954, an entire group of 11 *Eptesicus* taken from a vertical fissure in May's Cave, Monroe County, were females.

In Donnehue's Cave, some individuals appeared to prefer a certain section of the cave for roosting. For example, one was captured five times in section *H–I*. Another was found in section *E–F* four times. Another utilized section *A–B* in five instances; it was located near *B* on the sixth visit. Likewise, a final individual returned to section *G–H* five of six times. Many others seemed to choose a roosting site at random, but whether or not an individual actually "stakes out" a particular "range" requires more intensive study. There were definitely certain sites in the cave where clusters tended to form (points *C* and *F*.) These evidently were both favorable crevices, and often contained tightly packed aggregations which could not be removed for study.

Weights.—A series of weights of 87 marked bats (46 males and 41 females) was obtained between November 26 and March 8. During the study period, 25 of the males and 17 of the females were subsequently weighed from one to eight times each, thus affording some data regarding progressive weight loss during the winter.

Initial weights of the males averaged 17.9 grams, while the initial weights of females averaged 20.6 grams. It should be remembered, however, that some of this group were weighed for the first time in February or early March; they probably had already lost several grams after they first went into hibernation.

These data show that females averaged heavier than males. The maximum weight for a male was 22.4 grams, obtained November 30; the minimum was 12.9, on March 8. The heaviest female was also handled on November 30 and weighed 25.3 grams, while the lightest weighed 14.8 grams on March 8.

The weight loss over time has been compiled for 41 banded animals (25 males and 16 females) weighed more than once during the winter. The average number of days required to lose one gram of weight was calculated. This was found to vary from 6.6 to 50.8 days and may indicate the degree of movement among individuals. Males, on the average, required 22.1 days to lose one gram. Females averaged only 16.9 days per one gram loss in weight. Beer and Richards (1956) reported that in hibernating *Eptesicus* in Minnesota the males lost weight at a greater rate than the females. One of the bats (a female) removed from the cave on February 28, released in Bedford, and recaptured in the cave March 2 lost weight at the rate of a gram in 1.5 days.

It is not known whether *Eptesicus* fed during the winter but, as several authors have noted, feces were often passed by the bats while they were being handled. Insects of several species spent the winter in Donnehue's Cave. These included at least three species of flies, cave crickets, numerous mosquitoes, and at least two species of moths (including *Scoliopteryx libatrix*). In addition, cave spiders were plentiful. Although the greater horseshoe bat (*Rhinolophus ferrum-equinum*) is said to feed on *Scoliopteryx* and on cave spiders in Britain (Matthews, 1952), I have found no reference to this habit in *Eptesicus*. There certainly was not a sufficient amount of available food in the cave to sustain the wintering population of *Eptesicus* more than a very short time. Thus, if the bats did feed during hibernation (the progressive weight losses do not indicate this) they must have obtained food outside the cave. On unseasonably warm evenings in winter, in the Bedford area, it is not unusual to see great numbers of night-flying moths.

I found no indication that more frequent handling and weighing of the bats resulted in an increased weight loss. The largest weight loss, 6.2 grams, was exhibited by a female captured only twice, while another female handled eight times lost only 5.8 grams. My sample, however, is too small to be significant.

Copulation.—On two occasions, January 8, 1954, and February 7, 1955, I observed copulation of *Eptesicus* in Donnehue's Cave. One pair was situated in a crack in the ceiling; the other was clinging to a side wall. In both instances, copulation seemed to be prolonged. For example, the first pair was noticed copulating at 7:34 PM and was still thus engaged at 7:39 and 7:43 PM, but had terminated when I next checked at 8:17 PM. The second pair was found hanging about five feet from the ground and I grasped both in order to determine the sexes with certainty. When I released my hold (I had not removed them from the wall) the male flew, but the female remained quietly. When I returned 10 minutes later, they were again copulating, but the male flew a few moments after I placed the beam of my flashlight on them. Further

observations of copulation, in Indiana caves, were obtained November 23, 1951, and March 12, 1955. A pair "presumably copulating" was reported by Kirkpatrick and Conaway (1948) on December 27, 1946. These records establish the fact that copulation occurs over at least a five-month period.

Summary.—A wintering cave population of banded *Eptesicus fuscus* was intensively studied from August, 1954, through April, 1955, near Bedford, Indiana. Although at least 109 individuals utilized the cave, the maximum number observed on any one of 76 visits was 39 (36.1 per cent). This population exhibited constant fluctuation throughout the study period, bats entering and leaving freely.

The sex ratio of 107 marked bats was 55.1 per cent males.

Some data regarding progressive weight loss were obtained. The length of time required for an animal to lose one gram varied from 6.6 to 50.8 days. Female weights averaged more than those of males.

LITERATURE CITED

Beer, James R. 1955. Survival and movements of banded big brown bats. Jour. Mamm., 36: 242–248.

——— and A. Glenn Richards. 1956. Hibernation of the big brown bat. Jour. Mamm., 37: 31–41.

Blatchley, Willis S. 1897. Indiana caves and their fauna. Ann. Rep. Dept. Geol. and Nat. Resources, 1896: 121–212.

Griffin, Donald R. 1940. Notes on the life histories of New England cave bats. Jour. Mamm., 21: 181–187.

Guthrie, Mary. 1933. Notes on the seasonal movements and habits of some cave bats. Jour. Mamm., 14: 1–19.

Hitchcock, Harold B. 1949. Hibernation of bats in southeastern Ontario and adjacent Quebec. Canad. Field-Nat., 63: 47–59.

Kirkpatrick, Charles M. and Clinton H. Conaway. 1948. Some notes on Indiana mammals. Amer. Midl. Nat., 39: 128–136.

Matthews, L. Harrison. 1952. British mammals. London, p. 91.

Mohr, Charles E. 1945. Sex ratios of bats in Pennsylvania. Proc. Penn. Acad. Sci., 19: 65–69.

Rysgaard, G. N. 1942. A study of the cave bats of Minnesota with especial reference to the large brown bat, *Eptesicus fuscus fuscus* (Beauvois). Amer. Midl. Nat., 28: 245–267.

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THE LABORATORY CARE OF THE MEXICAN FREE-TAILED BAT

By Philip H. Krutzsch and S. Edward Sulkin

In order to better understand and appraise the possible role of the bat as a natural reservoir for the rabies virus it was found essential to maintain infected animals in captivity under controlled laboratory conditions for extensive periods of time. Of the species naturally infected with rabies virus that are known to occur in the United States (*Dasypterus floridanus, Lasiurus cinereus, L. seminolus, L. borealis, Myotis austroriparius, M. velifer, M. californicus, Eptesicus fuscus, Antrozous pallidus* and *Tadarida brasiliensis* [*mexicana* and *cynocephela*] only the immensely gregarious Mexican free-tailed bat, *Tadarida b. mexicana*, was readily available to us for laboratory study. This is a very sturdy species capable of withstanding considerable experimental trauma although its reluctance to accept food in capitivity foiled early attempts to keep it alive and healthy. Several investigators (Gates, 1936, 1938; Range, 1947; Constantine, 1952) failed in their attempts to adapt the Mexican free-tailed bat to life in captivity or found it possible to do so only under a regime which is impractical in studies involving the use of a large number of animals. After a series of pilot feeding experiments, a practical procedure was developed for maintaining these animals in a healthy state for long periods of time. It is the purpose of this report to describe in detail the methods which have given satisfactory results in the collecting, housing, feeding and experimental manipulation of the free-tailed bat. The authors are indebted to Miss Rae Allen and Mr. Craig Wallis for their generous assistance in these studies which have been supported by a grant from the Caruth Foundation of Dallas, Texas.

Experimental animals were obtained from the Blow-out Cave which is located on the Davis Ranch, near Fredericksburg, Blanco County, Texas. Bats inhabit this cave in large numbers, summer populations reaching several hundred thousand individuals. Collections were made during the daylight hours when sleeping bats were obtained from their roosting places on the walls and ceilings of the cave. Insect nets were used to scrape the bats from their resting places; the bats were then transferred from the nets to metal rat cages, were given water and kept cool while being transported to the laboratory. As pointed out by Eads *et al.* (1955) working conditions in the ammoniated atmosphere of the warm humid caves are very unpleasant. Those entering the cave were sprayed with an insecticide from an aeresol bomb (Airkem Company) to limit infestation by ectoparasites.

The handling of the bats during inoculation and transfer from the field to the laboratory cages was accomplished following a brief period (1–2 hours) of refrigeration at 4°C. This procedure inactivates the bats and facilitates handling them. After inoculation, bats were distributed into specially designed cages (Plate I) where they were to be housed for the duration of the experiment. Unless otherwise indicated, the bats were kept at 29°C. (relative humidity 60%).

A number of feeding techniques, together with numerous food combinations,

were attempted in order to induce the bats to accept food. In the initial attempts these animals were offered live mealworm larvae (*Tenebrio molitor*) in petri dishes. This procedure proved unsatisfactory. In subsequent attempts animals were fed a nutrient fluid containing amino acids, simple sugars and vitamins. Although such animals lived somewhat longer, they developed dysentery and succumbed within two to three weeks. The procedure which proved highly successful and which resulted in the laboratory maintenance of this species in a healthy state for several months consisted of the use of a mixture of

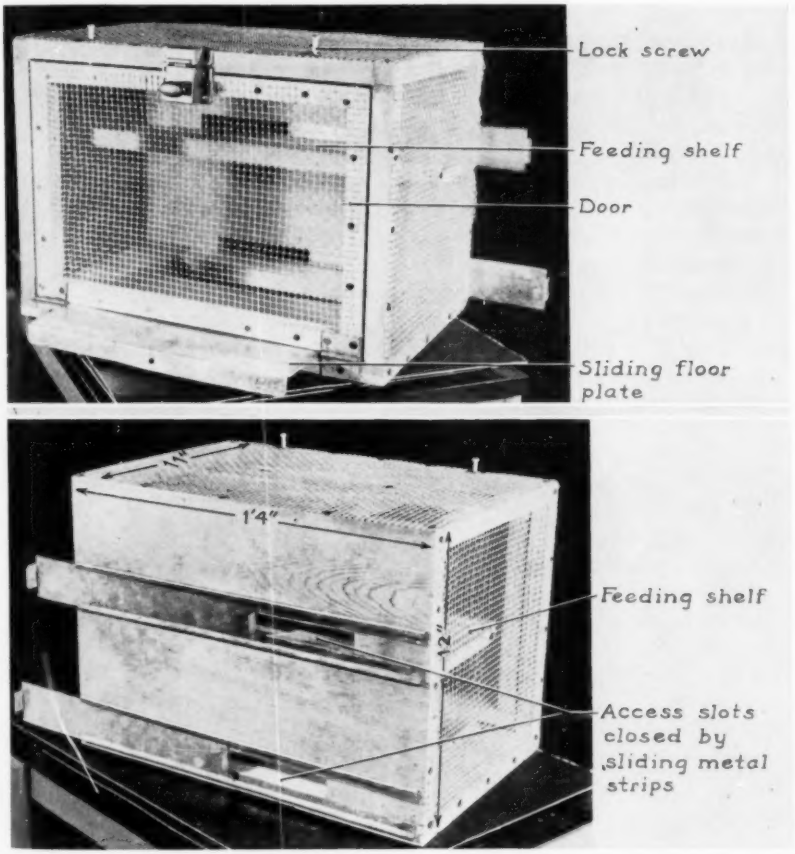

PLATE I

Front view (ABOVE) and rear view (BELOW) of safety cage used in housing bats infected with rabies virus.

approximately 1 lb. of large-curd cottage cheese, 1 large banana, 1 oz. of codliver oil and approximately 150 mealworms homogenized in a Waring blender. The roughage provided by the chitinous exoskeletons of the larvae prevented packing and resultant intestinal obstruction. This is in keeping with the suggestion by Gates (1938) that chitin seems to be necessary to maintain a healthy alimentary condition.

Food contained in open petri dishes was offered the bats through the access slots on the back of the cage (Plate I). Drinking water was also provided in an open dish which was filled by means of a long Pasteur pipette inserted through the wire mesh. This technique limited the hazard of infected animals and prevented their escape. Food and water were provided daily.

The cages for laboratory maintenance of bats incorporated special features designed to reduce the hazard of working with infected animals. Front and rear views of a cage are shown in Plate I. Slots provided with sliding metal strips are located on the rear of the cage and allow access to the feeding shelf and to the bottom of the cage, the latter for removal of dead animals. A sliding floor plate is provided for transfer of live animals from one cage to another. Lock screws to prevent inadvertent opening of the hinged door and of the sliding floor plate are additional safety precautions. These cages withstand repeated sterilization by autoclaving.

Krutzsch (1955) and Twente (1956) have presented information on the life history of the Mexican free-tailed bat. Their observations on the behavior of *Tadarida b. mexicana* in southern California and in south-central Kansas and north-central Oklahoma generally agree with those made by us on bats roosting in the Blow-out Cave, near Fredericksburg, Blanco County, south-central Texas. Bats are present in Blow-out Cave throughout the year but in midwinter (December, January and February) the population is reduced to a few scattered individuals that roost in narrow cracks in the walls or ceiling.

Bats brought to the laboratory in midwinter and early spring were more difficult to maintain than were individuals taken from nature in other seasons. This may be due to seasonal variation in the amount of stored fat. Some animals possibly do better because they have sufficient stored food to meet their metabolic needs until they learn to take food in capitvity. The lean animals may not survive such a fasting period.

In early spring bats of both sexes are usually without stored yellow fat and have only small amounts of interscapular brown fat. Males add some subcutaneous fat in the summer months whereas females continue to be lean throughout the summer and only start depositing fat as the young become self-sufficient. Adults of both sexes add fat and gain weight rapidly in the interval from late August to mid-October. There is increased interscapular (brown) fat as well as yellow fat, the latter having been deposited subcutaneously in the inguinal, axillary, costal and cervical regions and intra-abdominally throughout the viscera. Stored fats are gradually reduced during the winter and early spring months and animals are in general lean by spring.

SUMMARY

A practical procedure for laboratory feeding, safe housing and experimental manipulation of the free-tailed bat is presented. Remarks are made regarding a natural source of experimental animals and seasonal factors which may influence (at least in part) success in transfer of animals from nature to the laboratory.

LITERATURE CITED

CONSTANTINE, DENNY G. 1952. A program for maintaining the free-tail bat in captivity. Jour. Mamm., 33: 395–397.

EADS, R. B., J. S. WISEMAN, B. A. GRIMES, AND G. C. MENZIES. 1955. Wildlife rabies in Texas. Publ. Health Repts., 70: 995–1000.

ENRIGHT, JOHN B. 1956. Bats and their relation to rabies. Ann. Rev. Microbiol., 10: 369–392.

GATES, WILLIAM H. 1936. Keeping bats in captivity. Jour. Mamm., 17: 268–273.

————. 1938. Raising the young of red bats on an artificial diet. Jour. Mamm., 19: 461–464.

KRUTZSCH, PHILIP H. 1955. Observations on the Mexican free-tailed bat, *Tadarida mexicana*. Jour. Mamm., 36: 236–242.

PERRY, MARY LOUISE. 1947. Chiquito a guano bat. Nat. Hist., 56: 178–183.

RAMAGE, MARY C. 1947. Notes on keeping bats in captivity. Jour. Mamm., 28: 60–62.

TWENTE, JOHN W., JR. 1956. Ecological observations on a colony of *Tadarida mexicana*. Jour. Mamm., 37: 42–47.

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FEEDING HABITS OF THE SOUTHERN CALIFORNIA MOLE

BY JOHN NORMAN GRIM

The mole has been the object of various opinions and experiments regarding the amount of food normally consumed over a 24-hour period. Little actual work has been done in this field, and that has been with different species and has produced little statistical material. The purpose of this project was to compile more statistics and also develop information on another species of mole. In addition, some of the problems of feeding and keeping the moles were attacked and in some cases solved.

Two different types of food were used during the study and a percentage was calculated, in which the weight of food consumed was equal to a certain percentage of the body weight. The foods used included a dog food, of known constituents and percentages, and earthworms.

Over a period of about two months, six moles (*Scapanus latimanus occultus*) were captured, two of which died before usable results were obtained. The moles' weight upon capture averaged 55.0 grams with a low of 50.2 grams and a high of 59.5 grams.

Since there has been relatively little work of any type done with moles, a great deal of preparation was necessary before much could be accomplished. The first and most obvious problem was that of capturing the moles. All those eventually used were captured after flooding their burrows, this seeming to be one of the most successful methods. The second problem of significance

was that of acquiring sufficient natural food to feed the moles. This was easily solved by raising earthworms of a highly prolific variety. Having commenced with this particular part of the project somewhat late, the amount of statistical material that could be gathered using earthworms as food was limited.

The experimental techniques and conditions used closely paralleled those of previous experimenters (Fay, 1954; Willard, 1952) with only a few new techniques incorporated. The moles were kept in glass aquaria, 11½ in. long and 7½ in. wide and deep. The aquaria contained 3 to 4 inches of moist dirt sufficient for a small burrow system. They were covered with ¼-in. wire mesh which was itself weighed down well enough to restrain the moles. It was found that this species of mole had a definite need for water, at least under experimental conditions; consequently, bacteriological screw-cap culture tubes (16 by 125 mm.) were fitted with serum-bottle caps (medium plug, 3/8 in. long and 27/64 in. in diameter) and secured upside down in one corner of the cage. The rubber cap contained a small hole which allowed a continual film of water on the surface, from which the water was licked by the moles. This worked very satisfactorily and 5 to 10 cc. of water was taken during each 24-hour period. The two moles that died had not had water, and showed definite signs of needing it. These signs will be discussed under behavior. The dog food was placed on small platforms (4½ by 2 in.) which were suspended approximately ½ in. above the soil. It was found that the moles generally ignored food when covered with dirt, and this method greatly reduced that possibility. On the other hand, the earthworms were placed on the soil and covered with a thin, moist layer of dirt. In each case, after approximately 24 hours, the soil was sifted very carefully, the food sorted out and placed in a beaker, and the feces thrown away. About every two weeks the soil was remoistened thoroughly, as the burrows collapsed when dry. The soil was also replaced when definite odors of ammonia were detected. The uneaten food was washed free of dirt, drained of excess water and weighed. The dog food used was Dr. Ross's Horse Meat containing 95 per cent meat, 2.0 per cent ground bone, 2.9 per cent wheat flour, and minute amounts of seasoning and preservative; it also appeared to contain moderate amounts of fat which were almost invariably left uneaten. The moles adapted themselves to this new diet within one or two days. Most of the earthworms were a common variety in this area which is a cross between *Lumbricus terrestris* and *Helodrilus foetidus*. Each mole was weighed daily, to the nearest 0.1 gram. Weight changes were found significant in this series of experiments.

RESULTS

The average results obtained for each mole are recorded in Table 1. I have found only three instances of moles being fed dog food, horse meat, or similar types of food. Christian (1950) reported a figure between 50 and 55 per cent; Hisaw (1923) reported 32 per cent. Henning (1952) did not calculate the percentage, but judging from the amount of food the moles were given, it must have been near the average for the southern California mole as recorded in Table 1. As is evident from Fig. 1 and Table 1, the moles thrived (continually gaining weight) on the horse meat and maintained an average percentage of 70.2 per cent.

TABLE 1.—*The average percentage of food consumed over the experimental period by each mole, and also the number of days they were on the particular food. All specimens were males*

MOLE NO.	WEIGHT, GM.	DOG FOOD, %	NO. DAYS	EARTHWORMS, %	NO. DAYS
1	59.5	53.4	20	75.2	4
4	52.4	73.4	15	107.7	3
5	56.2	81.0	15	63.5	3
6	56.1	72.9	15	93.4	4
Avg.	56.0	70.2	—	84.9	–

As mentioned, there have been pronounced differences in results in various studies using earthworms as the food source. These results ranged from about 40 to 300 per cent. The results for this species averaged 84.9 per cent, and would probably have been higher if more time and worms had been available, since three of the four moles were eating more each day when the feeding ceased. Another noteworthy feature was the fact that each mole tended to either lose weight or remain about the same while being fed earthworms. Other possible explanations might account for this, such as a lesser percentage of fat in the earthworms as compared to the dog food. However, this seems improbable, since the fat in the dog food was usually left uneaten.

How "true to life" are these results? It must be realized that laboratory studies of this type can never completely duplicate the natural habitat. For example, the soil was loosely packed, whereas in nature it is usually packed appreciably harder; also, all needs for food

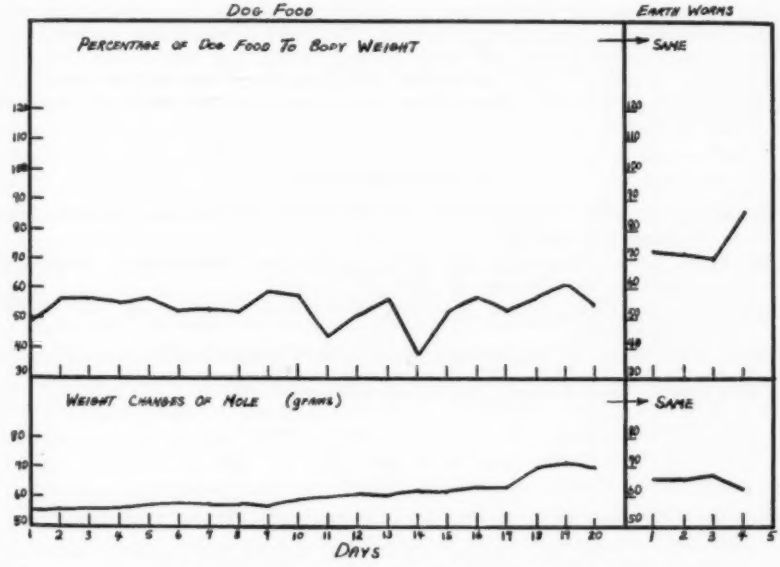

FIG. 1.—Amount of food consumed and weight changes in a southern California mole, specimen No. 1, fed on dog food and earthworms.

and water were readily satisfied, so little energy was expended to acquire food. Although the moles seemed quite active during their normally active hours, the obstacles ordinarily found in their natural habitat were not present in the laboratory. Knowing this, and the fact that all four moles gained weight quite consistantly, one might theorize that a near-normal appetite had been maintained, the accumulation of fat being then due to less activity in general. If this was the case, the results recorded may be fairly accurate. Much more work must be done along these lines before any definite and well-founded conclusions can be drawn.

During the course of study a number of behavioral reactions were observed. Before the water dispenser had been arranged, on occasions three of the moles, two of which died, were given a small amount of water in the bottom of a beaker in which they were temporarily contained. The reaction was a non-directional lapping, the tongue sometimes in and most of the time out of the water. The moles learned to use the water dispenser almost immediately and two were seen prying at the hole with a claw in order to get water to the surface. A unique method of eating the dog food consisted of scraping it directly into the mouth with the almost prehensile nose. Another habit is that of cleaning all living food with the front "hands" as it is taken into the mouth. Two interesting reactions were observed in regard to the hole from which the moles came to the surface for food. While retiring into this hole after eating, they nearly always closed the opening; but if they had not eaten, they simply scurried back into the hole without closing it. This usually happened when they appeared to be frightened by noises in the laboratory. From the surface, although known to be nearly or completely blind, they could find the open hole immediately, going directly to it. This may indicate a sense of direction and location, of orientation in general.

Occasionally, an indication of food preference was observed. This was determined by placing earthworms, Jerusalem crickets, slugs and isopods in containers with the moles. These foods were usually placed individually and two or three different kinds were not often together. The only criterion used was activity or degree of excitement of the mole; these were, however, very precise differences. The moles became highly excited in the presence of Jerusalem crickets and slugs, somewhat less so with isopods, and least with earthworms. These, of course, are general observations and were not performed in a particularly scientific manner. It should be mentioned that this excitement always culminated in eating the food.

LITERATURE CITED

CHRISTIAN, J. J. 1950. Behavior of the mole (*Scalopus*) and the shrew (*Blarina*). Jour. Mamm., 31: 281–287.

FAY, F. H. 1954. Quantitative experiments on the food consumption of *Parascalops breweri*. Jour. Mamm., 35: 107–109.

HENNING, W. L. 1952. Method for keeping the eastern mole in captivity. Jour. Mamm. 33: 392–395.

HISAW, F. L. 1923. Feeding habits of moles. Jour. Mamm., 4: 9–20.

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BLOOD COMPOSITION OF WHITE-TAILED DEER

By A. E. Teeri, W. Virchow, N. F. Colovos and F. Greeley

In recent years overpopulation of deer and consequent decline in quality and quantity of natural forage in many states have attracted the attention of wildlife biologists to the nutritional requirements of deer (French *et al.*, 1955) and the effects of malnutrition. Blood analyses of both wild and penned deer have been made in searching for correlations between elements of the blood and nutritional condition or disease. (Browman and Sears, 1955; Leopold *et al.*, 1951; Maynard *et al.*, 1935; Rosen and Bischoff, 1952; Whitlock, 1939). During February and March, 1955, blood samples were collected from white-tailed fawns, *Odocoileus virginianus*, which had been used in digestion tests of natural forages at the University of New Hampshire Animal Nutrition Laboratory. Observations made of the formed elements and chemical constituents of the blood are reported herein.

Materials and methods.—Eight male fawns from Maine and New Hampshire were brought to the campus in October, 1954. They were housed in a 16 × 16 foot unheated shed with attached corral. They were fed a 16 per cent dairy feeding ration, a nutritionally balanced ration for growing ruminants, at the rate of about 2.0 pounds per animal daily. Water was available at all times. Digestion trials of natural forages were begun on December 11, 1955. The forages tested were hemlock (*Tsuga canadensis*), mountain maple (*Acer spicatum*), and apple (*Malus* sp).

Three of the deer were used on digestion trials once and were in too poor health to be used again. Four others were used three or four times and one was never in good enough health to be used for digestion trials. Body weight changes were recorded only during successful trials and then only after a pretrial period of adjustment to the browse, which generally lasted approximately 7 to 10 days. During the adjustment period and the trials, the deer were fed only the browse to be tested. Judging from previous experience with deer in this laboratory, it was apparent that all but one of the deer were underweight (less than 60 lbs.) in December, the first time they were weighed. The one exception, No. 94, weighed 80 pounds in December and declined to 70 pounds soon thereafter. We have estimated that the seven deer used on digestion trials lost a minimum of 19 to 23 per cent of their December weight during the winter. Three of the deer (Nos. 79, 87 and 91) died with less than 2 per cent of fat in the femur bone marrow (Cheatum, 1949). A total absence of methane production (Ritzman and Benedict, 1938) during metabolism tests at the end of each digestion trial may have been correlated with the poor nutritional condition of the deer. These observations are indicative of the poor nutritional status of these deer when blood samples were taken in late winter.

Blood samples were taken on February 21, 28 and March 28, 1955, with an 18-gauge hypodermic needle inserted into the jugular vein. The animals were confined singly to a small pen, thrown by force and stretched on a platform for

collection of the blood. Amounts collected ranged from 20 to 100 ml. The blood was placed immediately in Erlenmeyer flasks containing known amounts of crystalline heparin. Smears of fresh unherparinized blood were taken for differential white cell counts, which were made in the usual manner in the University hospital laboratory. The following symptoms resulted in a period of about ten minutes before bleeding, during which the deer were under extreme nervous and muscular tension: panting and frothing at the mouth occurred in all of them; in at least one case, internal injury was later found, which probably occurred at the time of handling. In our experience, keeping even a very tame deer quiet enough to collect large samples of blood is extremely difficult and we feel that blood elements capable of rapid change can be influenced by the type of handling used here. These results must, therefore, be considered with the dual stresses of malnutrition and handling in mind.

The methods used in chemical analysis were those of Folin and Wu (1920) for glucose, Fiske and Subharow (1925) for phosphorus, Whitehorn (1920) for chloride, Koch and McMeekin (1924) for non-protein nitrogen, Van Slyke and Cullen (1916) for urea, Brown (1945) for uric acid and Clark and Collip (1925) for calcium. Smears were stained with Wright's hematoxylin and eosin. Total white cells and erythrocytes were counted in a Spencer Brightline hemocytometer. Sedimentation rates were determined as soon as possible after withdrawal of the blood on undiluated, heparinized blood in a graduated tube with a Westergren millimeter scale. Hemoglobin was determined in a Sahli hemoglobinometer. The methods followed for counting the formed elements, and for determination of sedimentation rates and hemoglobin are described in Youmans (1940) and Gradwohl (1943).

Results and Discussion.—The results of chemical analyses are shown in Table 1. In general, the values are within the range to be expected for ruminants and in many instances are quite similar to those reported for calf blood (Teeri *et al.*, 1946). An exception is the higher values for non-protein nitrogen. These values are similar to those found by Maynard *et al.* (1935) in white-tailed deer. Of twelve values for blood glucose concentration, five were lower than the lowest value reported by Maynard *et al.* for a pregnant doe and eight were less than the minimum for a healthy buck. As would be expected, low glucose concentration was observed in animals in poorest condition; the three deer which died in a severe state of starvation within 1 to 23 days after the last blood sample was taken, had blood sugar concentrations varying from 43 to 60 mg per 100 ml. The two deer in the best condition had some of the highest blood sugar levels. These varied from 69 to 86 mg. per 100 ml.

Urea nitrogen concentrations were generally higher than those reported by Maynard *et al.* Although the variation in these values was not great, there was a tendency toward direct correlation between urea nitrogen and blood sugar, possibly resulting from gluconeogenesis from protein. Uric acid, on the other

TABLE 1.—*Chemical composition of deer blood; all values in mg./100 ml. whole blood except calcium (mg./100 ml. serum)*

DEER NO.	GLUCOSE			INORGANIC P			NaCl			NPN			UREA N			URIC ACID			CALCIUM		
	Feb. 21	Feb. 28	Mar. 28	Feb. 21	Feb. 28	Mar. 28	Feb. 21	Feb. 28	Mar. 28	Feb. 21	Feb. 28	Mar. 28	Feb. 21	Feb. 28	Mar. 28	Feb. 21	Feb. 28	Mar. 28	Feb. 21	Feb. 28	Mar. 28
79*	—	43	—	—	2.2	—	—	274	—	—	50.0	—	—	26	—	—	0.8	—	—	9.2	—
86	—	69	—	—	2.8	—	—	291	—	—	48.6	—	—	25	—	—	0.9	—	—	10.4	—
87*	—	67	60	—	2.2	3.6	—	280	245	—	53.0	46.0	—	24	28	—	1.1	0.8	—	8.7	9.7
88	86	—	—	3.1	—	—	283	—	—	38.0	—	—	25	—	—	1.0	—	—	8.8	—	—
91*	77	—	53	5.1	—	3.8	280	—	245	40.0	—	52.0	34	—	29	1.0	—	0.8	—	—	8.8
92	—	65	—	—	3.7	—	—	283	—	—	52.6	—	—	25	—	—	0.7	—	—	8.6	—
93*	76	—	54	2.3	—	2.2	290	—	225	47.0	—	44.0	27	—	24	0.9	—	1.3	10.2	—	9.8
94	—	84	69	—	7.0	4.9	—	284	236	—	49.9	39.0	—	25	23	—	0.7	0.8	—	10.6	10.6
Mean	79	66	59	3.5	3.6	3.6	284	282	238	41.6	50.8	45.2	29	25	26	1.0	0.8	0.9	9.5	9.5	9.7

* Nos. 79, 87 and 91 died in a state of starvation 1–21 days after the last blood sample; No. 93 was fatally crippled during handling.

hand, varied little and showed little correlation with the condition of the animals.

Serum calcium and non-protein nitrogen were similar to the values observed by Maynard *et al.* No relationship to malnutrition appeared. Sodium chloride levels did not appear to be related to the condition of the deer although they declined markedly in the four animals sampled March 28, regardless of their condition. Inorganic phosphate was lowest in the most starved animal (No. 79) and highest in the deer in best condition and weight (No. 94).

Cell counts, hemoglobin concentration and sedimentation rates are shown in Table 2. Rosen and Bischoff (1952) have shown a tendency for the number of red blood cells and the hemoglobin concentration to decline in mule deer on overstocked ranges and have given correlation coefficients of these two blood factors with body weights. Browman and Sears (1955) obtained lower values for erythrocytes and hemoglobin in female Rocky Mountain mule deer (*O. h. hemionus*) in poor health. Our data are insufficient for statistical appraisal but such correlations do not appear on an individual basis. Deer No. 79 had a higher erythrocyte count and hemoglobin concentration on February 28 than No. 94, which was nearly twice as large. No. 79 died within

TABLE 2.—*Cell counts, hemoglobin and sedimentation rates in deer blood, 1955*

DEER NO.	ERYTHROCYTES, *millions/cu.mm.*		HEMOGLOBIN, *gm./100 ml.*		SED. RATE, *mm./hr.*, WESTERGREN		WHITE COUNT, *thousands/cu.mm.*	
	Feb. 28	Mar. 28	Feb. 28	Mar. 28	Feb. 28	Mar. 28	Feb. 28	Mar. 28
79*	19.5	——	20.0	——	14	—	5.90	
86	21.2	——	24.6	——	1	—	5.95	
87*	10.8	16.68	11.9	17.5	61	7	4.80	4.90
91*	——	23.08	——	20.0	—	7	——	5.55
92	16.5	——	17.1	——	6	—	5.15	
93	——	20.06	——	18.0	—	54	——	4.70
94	17.0	23.30	17.4	21.0	2	3	6.20	3.70

Differential white cell count, per cent

DEER NO.	NEUTROPHILS		LYMPHOCYTES		MONOCYTES		EOSINOPHILS		BASOPHILS	
	Feb. 28	Mar. 28	Feb. 28	Mar. 28	Feb. 28	Mar. 28	Feb. 28	Mar. 28	Feb. 28	Mar. 28
79*	67	—	29	—	4	–	0	–	0	
86	38	—	55	—	4	–	2	–	1	
87*	28	17	64	77	3	3	4	1	1	2
91*	—	22	—	73	–	3	–	1	–	2
92	34	—	61	—	2	–	1	–	2	
93	—	45	—	48	–	3	–	3	–	1
94	35	17	59	72	2	3	3	5	1	3

* Died within 21 days with fat content of the femur bone marrow at starvation levels (less than 2 per cent).

24 hours with a femur bone marrow fat content of less than 2 per cent. Deer No. 91 died in the same nutritional condition with pneumonia and a blood clot in the lower abdomen 18 days after the last blood sample on March 28. Thus, 2½ weeks before his death his erythrocyte count and hemoglobin concentration were among the highest recorded values. No. 87 was sampled on February 28 and March 28 and died with an acute intestinal blockage (intussusception) and a marrow fat content of less than 2 per cent on April 18. On February 28 his erythrocyte count and hemoglobin concentration were the lowest recorded, but by March 28 they had risen to moderate levels. It is unfortunate that more blood samples from these individuals were not taken but, compared with the values from the healthiest animal in the herd (No. 94), there was no apparent relationship with nutritional condition.

Sedimentation rates varied widely (1–61 mm./hour) and tended to be higher in weaker animals than in stronger ones.

The total white cell counts gave no indication of a correlation with nutritional condition although some interesting relationships appeared in the differential counts. Generally the per cent of polymorphonuclear leucocytes was lower than that of lymphocytes but in No. 79 the reverse was true. Eosinophil counts also tended to be low in those individuals in poorest condition (No. 79, 87, 91 and 93), possibly as a result of environmental stress. A decline in eosinophils has frequently been observed in laboratory mammals and human beings subjected to stressful environmental stimuli, or to injections of adrenocorticotrophin or adrenal corticoids (Thorn *et al.*, 1947).

It is felt that the number of animals involved in this study is too small to permit statistical evaluation of the data. The manner in which the data were collected, incidental to nutritional experiments, also does not lend itself to more than individual evaluation of the animals and their blood components. A more comprehensive study of blood elements in deer under controlled levels of starvation or malnutrition might bring out some of the variations observed here more clearly. Changes in blood sugar levels, and their relationship to products of protein catabolism, as well as the various cell counts, might reveal changes which could be related to malnutrition in wild deer by techniques applicable in the field. So long as overpopulated deer ranges continue to exist, such studies will be important.

Summary.—The indications from this study are that malnutrition in male white-tailed deer fawns produced hypoglycemia with a corresponding increase in protein catabolism as reflected by slightly elevated blood urea concentrations. Elevated sedimentation rates, polymorphonuclear leucocytosis, and low levels of inorganic phosphate may also have occurred at some state in malnutrition. There was little evidence of anemia.

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operation with the N.H. Agricultural Experiment Station and the N.H. Engineering Experiment Station. The eight deer were supplied by the Maine Dept. of Inland Fisheries and Game and by the N. H. Fish and Game Dept. Collection of blood samples was aided by F. E. Allen, H. A. Laramie and J. A. Lee.

LITERATURE CITED

Browman, L. G. and H. S. Sears. 1955. Erythrocyte values, and alimentary canal pH values in the mule deer. Jour. Mamm., 36: 474–476.

Brown, H. 1945. The determination of uric acid in human blood. Jour. Biol. Chem., 158: 601–608.

Cheatum, E. L. 1949. Bone marrow as an index of malnutrition in deer. N.Y. State Cons. 3(5): 19–22.

Clark, E. P. and J. P. Collip. 1925. Study of the Tisdall method for the determination of blood serum calcium with a suggested modification. Jour. Miol. Chem., 63: 461–464.

Fiske, C. H. and Y. Subbarow. 1925. The colorimetric determination of phosphorus. Jour. Biol. Chem., 66: 375–400.

Folin, O. and H. Wu. 1920. A system of blood analysis. Suppl. I: A simplified method for determination of sugar. Jour. Biol. Chem., 41: 367–374.

French, C. E., L. C. McEwen, N. D. Magruder, R. H. Ingram and R. W. Swift. 1955. Nutritional requirements of white-tailed deer for growth and antler development. Agr. Exp. Sta. Bull. 600, Pa. State Univ.

Gradwohl, R. B. H. 1943. Clinical laboratory methods and diagnosis. C. V. Mosby Co., St. Louis. 1076 pp.

Koch, F. C. and T. L. McMeeken. 1924. A new direct Neslerization Micro-Kjeldahl method and a modification of the Nessler-Folin reagent for ammonia. Jour. Amer. Chem. Soc., 46: 2066–2069.

Leopold, A. S., T. Riney, R. McCain and L. Tevis, Jr. 1951. The Jawbone deer herd. Game Bull. 4, Calif. Div. of Fish and Game.

Maynard, L. A., G. Bump, R. W. Darrow and J. C. Woodward. 1935. Food preferences and requirements of the white-tailed deer in New York State. N.Y. State Cons. Dept. and N.Y. State Coll. Agr., Joint Bull. 1.

Ritzman, E. G. and F. G. Benedict. 1938. Nutritional physiology of the adult ruminant. Carnegie Inst. Wash., Publ. 494: 24–30.

Rosen, M. N. and A. I. Bischoff. 1952. The relation of hematology to condition in California deer. Trans. N.A. Wildl. Conf., 17:482–496.

Teeri, A. E., H. A. Keener and K. S. Morrow. 1946. Studies on the chemical composition of calf blood. Jour. Dairy Sci., 29: 663–667.

Thorn, G. W., F. T. G. Prunty and P. H. Forsham. 1947. Clinical studies on the effects of pituitary adrenocorticotropic hormone. Trans. Assoc. Amer. Physicians, 60: 143–150.

Van Slyke, D. D. and G. E. Cullen. 1916. The determination of urea by the urease method. Jour. Biol. Chem., 24: 117–122.

Whitehorn, J. C. 1920. A system of blood analysis. Suppl. II: Simplified method for the determination of chlorides in blood or plasma. Jour. Biol. Chem., 45: 449–460.

Whitlock, S. C. 1939. Studies on the blood of white-tailed deer. Jour. Wildl. Mgmt., 3: 14–16.

Youmans, J. B. 1940. Essentials of the diagnostic examination. Commonwealth Fund, New York. 417 pp.

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ADDITIONAL MAMMAL RECORDS FROM THE BONNEVILLE BASIN, UTAH

By E. A. Shippee and Harold J. Egoscue

When Durrant prepared his "Mammals of Utah, taxonomy and distribution" (Univ. Kans. Publ., Mus. Nat. Hist., 6:1–549, 1952) he had comparatively few specimens and records of some kinds of mammals from the Bonneville Basin, particularly from Tooele County. Intensive field work from 1951 to 1955 in Tooele County and other parts of the western Utah desert has extended the known ranges of several mammals to include the northern Bonneville Basin. These records, together with additional specimens and records of certain little-known species already reported from the area, are the basis for this paper.

"Specimens examined" are in the collections of Ecological Research at Dugway, Utah; the "other records" resulted from special studies where the mammals collected were identified and recorded but were not prepared as specimens.

Most of the present and former members (both civilian and military) on the staff of Ecological Research have contributed time and effort collecting specimens and recording data used in this report. S. D. Durrant confirmed the identification of some of the cottontail rabbits and critically read the manuscript. This work was supported in part by U.S. Army Chemical Corps contracts, Nos. DA-18-108-CML-4776 and DA-18-064-CML-2455, with the University of Utah.

LIST OF SPECIES

***Sylvilagus auduboni arizonae*?** (Allen), Audubon cottontail.—A specimen from Gold Hill, Tooele County, extends the known area of occurrence approximately 40 miles northward. Other records and specimens from the intervening valleys and foothills of desert ranges between the Stansbury and Deep Creek mountains (1951–1955) indicate that this cottontail is uncommon in suitable habitats throughout the area. Cottontails reported (*in verbis*) by several persons to occur in the Newfoundland Mountains, a low desert range in Boxelder County, may also prove to be of this species.

As previously stated by Durrant (*op. cit.*: 86), the taxonomic status of the Audubon cottontail in the Bonneville Basin still awaits satisfactory solution.

Specimens examined.—Total 5, distributed as follows: *Tooele Co.*: 1 mi. NW Gold Hill, 1; west side Camel Back Mt., 1; SE end Camel Back Mt., 1; north end Granite Mt., 1; Round Mountain (Little Granite Mt.), 1.

Other records.—Total 6, distributed as follows: *Tooele Co.*, 6 mi. SE Wig Mt., 1; north end Camel Back Mt., 1; 4 mi. E Simpson Buttes, 1; SE end Cedar Mts., 1; Skull Valley, 7 mi. SW Orr's Ranch, 1. *Juab Co.*: Callao, 1.

Marmota flaviventer avara (Bangs), yellow-bellied marmot.—When Durrant prepared his accounts of marmots, he had neither specimens nor records of their occurrence from the Deep Creek Mountains (*op. cit.*: 101–105). Subsequent work by R. M. Hansen (unpublished master's thesis, Univ. Utah Zool. Dept., 1951) produced neither specimens nor sight records of marmots from these mountains. He mentioned, however, reports by local residents of their presence and believed that when specimens were collected they would be referable to *M. f. avara*.

Ordinarily sight records are not satisfactory for establishing the occurrence of animals, but the marmot is distinctive in appearance and is not likely to be confused with any other

mammal in the vicinity. A marmot was seen by one of us (H. J. E.) from a distance of about 30 feet, on June 30, 1955, as it sat in a trail near the headwaters of Granite Creek (elevation 8,500 feet) on the east side of Deep Creek Mountains in Juab County. Assignment of this animal to the subspecies *M. f. avara* is based purely on geographical distribution and follows E. R. Hall (MAMMALS OF NEVADA, Univ. Calif. Press, Berkeley, Calif., 1946: 285) who assigned to this race marmots from the Snake Range, a short distance to the southwest, in Nevada.

Eutamias dorsalis utahensis Merriam, cliff chipmunk.—Durrant (*o. cit.*: 150) gave the distribution of this chipmunk as "probably state-wide in the mountains, limits unknown." Because specimens had not been collected from the Bonneville Basin, Durrant, in preparing the distribution map for *E. d. utahensis*, did not include the area westward from the Wasatch Mountains to the Nevada line (except the Raft River Mountains in the extreme northwest) within the range of this subspecies. Specimens have since been taken from the Stansbury and Deep Creek mountains and from several intervening lower desert ranges, thus indicating that this chipmunk may be found in suitable habitat throughout most of the western part of the state.

The taxonomic status of the cliff chipmunks occurring in the Deep Creek Mountains is questionable since Hall (*op. cit.*: 349) assigned specimens from northeastern White Pine and eastern Elko counties along the eastern Nevada border to the subspecies *E. d. grinnelli*. Because only one specimen, a female in very worn pelage, is available from the Deep Creek Mountains, this question remains unresolved.

Specimens examined.—Total 9, distibuted as follows: *Tooele Co.*: East slope Granite Peak (Granite Mt.), 1; Cane Springs, Cedar Mts., 5,400 ft., 3; Stansbury Mts., west side, 3 mi. N Johnson Pass, 1; West Hickman Canyon, 1; Rock Springs Canyon, 1. *Juab Co.*: Granite Creek, Deep Creek Mts., 6,800 ft., 1.

Other records.—Total 34, distributed as follows: *Tooele Co.*: Gold Hill, 1; Mine Canyon, north end Granite Mt., 3; Stansbury Mts., Ahlstrom Mine Canyon, 18; Willow Springs, 1; ½ mi. E Willow Springs, 5; Narrows, Johnson Pass, 6.

Perognathus longimembris gulosus Hall, little pocket mouse.—From the available material, Durrant (*op. cit.*: 237) concluded that this mouse was restricted to the extreme western part of Utah. At that time, only one specimen had been collected north of the 39th parallel. Subsequently, Hansen (*op. cit.*) collected another specimen in the eastern foothills (elevation 5,600 feet) of the Deep Creek Mountains, Juab County. Additional specimens are now available from several localities in south-central Tooele County and from Callao in Juab County. The easternmost records are from large, semistabilized dunes at the north base of Little Granite Mountain in Tooele County. These extend the known range of the little pocket mouse about 40 miles to the east; *P. l. gulosus* is believed to occur throughout the northern Bonneville Basin wherever suitable edaphic conditions are found. These mice appear to be most abundant in loose, sandy soils or in similar soils containing very fine gravel.

Specimens examined.—Total 11, distributed as follows: *Tooele Co.*: 7 mi. NE Granite Peak (Granite Mt.), 2; 6 mi. N Camel Back Mt., 3; ½ mi. E Wig. Mt., 1; N Wig Mt., 2; north end Little Granite Mt., 2. *Juab Co.*: 1 mi. S Callao, 1.

Other records.—Total 3, distributed as follows: *Tooele Co.*: S end Cedar Mts., 1; Simpson Buttes, 2.

Microdipodops megacephalus leucotis Hall and Durrant, dark kangaroo mouse.—Since its original description (Hall and Durrant, Murrelet, 22:, 1941) this mouse has been known only from the type specimen. Additional collecting has shown *M. m. leucotis* to be extremely local and discontinuously distributed in vegetated dunes along the valley floors of the Bonneville Basin in south-central Tooele County. Traplines set for several nights in seemingly ideal habitat often will not take a single kangaroo mouse. Aside from topotypes, specimens are known from various localities between Little Granite Mountain (about 5 miles east of

the type locality) and Granite Mountain about 30 miles to the west. None have been collected in Juab County. The distributional limits are still unknown.

Because the type is the only recorded specimen, the following data are considered to be worthwhile. Extreme and average measurements (mm.) of 10 adult males and 12 adult females respectively are as follows: Total length, 136–160 (145.4) and 140–158 (148.6); length of tail, 71–92 (77.6) and 75–89 (81.5); length of hindfoot, 20–24 (22.4) and 22–24 (23.04); length of ear from notch, 8–11 (9.6) and 7.5–11 (9.5). Extreme and average weights (gm.) based on 4 males and 8 females, respectively, are as follows: 9.5–10.8 (10.2) and 9.3–12.3 (10.7). Females average slightly larger than males in all except the ear measurement.

Specimens examined.—Total 27, distributed as follows: *Tooele Co.*: 7 mi. NE Granite Peak (Granite Mt.), 4; 3 mi. N Granite Mt., 1; 5 mi. N Granite Mt., 1; 7 mi S Wig Mt., 12; 5 mi. SW Wig Mt., 2; 6 mi. SW Wig Mt., 1; Cedar Mts., 3 mi. W Sand Pass, 1; 5 mi. N Camel Back Mt., 2; 1 mi. W Granite Mt., 1; 4 mi. E Camel Back Mt., 1.

Neotoma cinerea acraia (Elliot), bushy-tailed woodrat.—Durrant (*op. cit.*: 345) had specimens of this rat from only one area that is well within the Bonneville Basin, namely eastern Tooele County. Consequently he excluded most of the Bonneville Basin as being within the range of *N. c. acraia.* Hansen (*op. cit.*) recorded one specimen from the Deep Creek Mountains which he referred to this subspecies. Specimens are now available from the Cedar Mountains (highest elevation about 7,750 feet), a low, almost waterless desert range in central Tooele County. Bushy-tailed woodrats may also occur in other similar mountains within the Bonneville Basin. Other records of occurrence were obtained in both the Stansbury and Deep Creek mountains. Where bushy-tailed woodrats and desert woodrats were collected in the same area, *N. cinerea* usually was found in the higher, more extensive cliffs, while *N. lepida* occupied the rubble at the base of these cliffs, or crevices of the smaller ledges and outcroppings. Bushy-tailed woodrats apparently do not build houses, as such, in this area, but prefer deep fissures, natural caves and mine workings.

Specimens examined.—Total 5, distributed as follows: *Tooele Co.*: ¼ mi. N Cane Springs, Cedar Mts., 5,800 ft., 5.

Other records.—Total 10, distributed as follows: *Tooele Co.*: Stansbury Mts., Ahlstrom Mine Canyon, 1; Rock Springs Canyon, 1; Johnson Pass, 6. *Juab Co.*: Granite Creek, Deep Creek Mts., 2.

Rattus norvegicus norvegicus (Berkenhout), Norway rat.—Although this introduced species is commonly found in most of the larger cities and the more densely settled farming communities of central Utah from Sevier County northward (Durrant, *op. cit.*: 383), it has seldom been reported from the arid, sparsely settled western part of the state. Specimens were collected August 31, 1954, from the granaries of the Dymock Ranch on the southeast end of the Stansbury Mountains about 3–4 miles west-northwest of Clover, Tooele County. Immature as well as adult animals were trapped, indicating the species to be well established. The Dymock Ranch is located about 5 miles west of St. John, where Harmston (THE RAT PROBLEM IN UTAH, State Dept. of Health, Salt Lake City, 1951) found these rats occurring during the period 1949–1951.

A few Norway rats have been trapped in buildings at Dugway Proving Ground, probably having arrived in shipments of household goods or in produce trucks. Thus far this animal does not seem to have become permanently established as a breeding species in the Dugway area.

Ecological Research, Univ. of Utah, Dugway. Received January 8, 1957.

THE MUNSELL SYSTEM OF COLOR NOTATION

By Richard S. Miller

Ridgway's COLOR STANDARDS AND COLOR NOMENCLATURE has been the accepted reference for color description in biology since its publication in 1912, but this work has long been out of print and modern methods of color analysis show that the existing copies are no longer technically reliable (Illman and Hamly, 1948). Davis (1956) has recently discussed the need for a new color standard and the purpose of this paper is to examine some of the requirements of an adequate color standard with special reference to the Munsell System as a possible candidate.

I would like to express my appreciation to Mr. W. N. Hale of the Munsell Color Company, Inc. for advice during the preparation of this manuscript.

COLOR DESCRIPTION IN BIOLOGY

Color description in biological research falls into two general categories: (1) characterization of the typical or predominant color of a population and (2) detailed analysis of individual variation within a population. Since these two categories of color description have different technical requirements, methods which are suitable for one are not always suitable for the other. In taxonomic description, for example, one selects a sample of typical individuals from a population or series of populations and describes the color characters of a species or subspecies on the basis of this sample. Less commonly, a taxonomist may present descriptions of the extremes of observed variation and attempt to establish mean color and range of variation, but in either case his objective is usually a characterization that is typical for the population. Since this type of description consists mostly of approximate descriptions and does not stress subtle variations as a general rule, color characters are usually determined by comparing the specimens with a color chart system such as Ridgway's COLOR STANDARDS (1912), the Maerz and Paul DICTIONARY OF COLOR (1950), or the Villalobos ATLAS DE LOS COLORES (1947).

The analysis of individual color variation requires greater accuracy in that absolute color matching of the specimen and sample or absolute measurement are involved, and colorimetric methods such as those described by Sumner (1927) and Durham (1941) have been used in work of this nature; but, as Davis (1956) points out, the rather elaborate devices that are required for most forms of colorimetry do not appeal to the average taxonomist and they are seldom adopted for general color description.

THE MUNSELL COLOR SYSTEM

Color-reference material is classified by Foss (1949) as follows: (1) colorant-mixture systems, (2) color-mixture systems and (3) color-appearance systems. Of the various chart systems that have been used in biology, Ridgway's COLOR STANDARDS is an example of a color-mixture system, the Maerz and Paul DICTIONARY OF COLOR is a combination of color-mixture and colorant-mixture,

and the Munsell System of Color Notation is a color-appearance system. A disadvantage of the color-mixture and colorant-mixture systems is that their color samples are defined in terms of the amounts of colors or colorants used to make them, and they do not account for visual evaluation of the different colors. The Maerz and Paul DICTIONARY OF COLOR, for example, consists of eight chromatic inks used in paired combinations, each printed in a series of eight charts in which succeeding pages are darkened by overprinting with successively darker transparent gray ink (Foss, 1949). The result of this process is that a large number of color samples can be produced at a relatively low cost, but certain color regions are represented by very similar color samples while darker regions are covered by fewer samples. In the Munsell System, the concept of uniform spacing of colors is designed to be valid for any normal observer. The principal feature of this system is a method of color notation in which the three color attributes of hue, value, and chroma are arranged in scales of equal visual distance. The Munsell System can be represented by a color solid with the value scale running vertically from a theoretically pure black at the bottom to a theoretically pure white at the top; a series of constant-hue planes radiate from a central axis with the neutral value plane at its center; and each hue plane shows its own range of value and chroma in rectangular coordinates.

Chromatic colors are divided into five principal classes(red, yellow, green, blue, and purple) and five intermediate hues (yellow-red, green-yellow, blue-green, purple-blue, and red-purple) as shown in Fig. 1, so that the hue notation

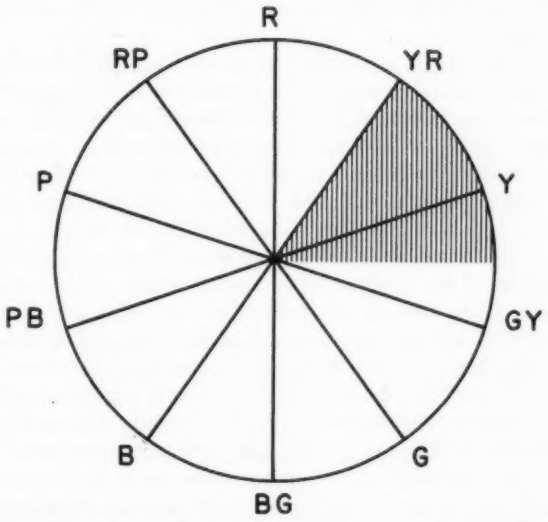


FIG. 1.—Typical hue circle of 5 principal and 5 intermediate hues. Hue range of SOIL COLOR CHARTS shown by crosshatched area.

for a color shows its relation to the principal or intermediate hues or any of their subdivisions. The hue names may again be combined to form such combinations as red-yellow-red when finer subdivisions are needed, or each hue may be divided into ten steps (e.g., 1R to 10R, 1YR to 10YR) to increase the hue notation to 100. The value notation indicates the degree of lightness or darkness of a color in relation to a neutral gray scale extending from theoretically pure black (0/) to theoretically pure white (10/). The chroma notation shows the strength or saturation of a color, or its departure from a neutral gray of the same value, extending from /0 for neutral gray to higher numbers corresponding to the saturation of the individual color.

A complete Munsell notation is written in the form "hue value/chroma," so that a dark red might be shown as 5R 3/6; decimals are used when a finer subdivision is needed for any of the three color attributes, as in the case of an olive brown with the Munsell notation 2.5Y 5/4.5.

COLOR NOMENCLATURE

It is esthetically more acceptable to many workers to use color names rather than numerical designations (Barnes, 1949), although Davis (1956) argues that "a more reddish tint than Prout's Brown, and slightly darker" conveys no more indication of actual color than does its equivalent numerical designation in a color system. Certainly many of the more bizarre names in Ridgway's nomenclature are only understood because they have been used so often that they are a traditional fixture in the literature, and what Davis (1956) refers to as "wild extrapolations from Ridgway" are not particularly meaningful; but the name of a color, if sensibly chosen, adds much to the understanding of a color description.

The use of color names is provided for in the Munsell System by the ISCC-NBS method of color designation in conjunction with the appropriate Munsell notation (Nickerson, 1956). The ISCC-NBS method uses the terms "light," "medium" and "dark" to designate degree of lightness or darkness and the adverb "very" to extend this scale in either direction. The adjectives "grayish," "moderate," "strong" and "vivid" show color strength; and these and a series of hue names combine to describe a color according to its visual attributes of hue, lightness and strength or, in Munsell terms, hue, value and chroma. An important feature of this method is that the boundaries of each name designation are fixed in terms of Munsell notations, so that each color designation with its hue name and modifiers defines a block in the color solid, as shown in Fig. 2.

Hamly (1949) has correlated Ridgway's COLOR STANDARDS with the Munsell BOOK OF COLOR to compile a list of equivalent Munsell notations for the Ridgway color names. Hamly feels that this key will prolong the usefulness of data already recorded in Ridgway terms, but does not recommend it for new observations with Ridgway color names, since the color imperfections that were originally present in the COLOR STANDARDS and those that have since been produced by aging and wear make it impossible to prepare a key which would be applicable to all copies of Ridgway.

MUNSELL COLOR MATERIALS

The Munsell Color Company, Inc. produces a variety of color-reference materials, many of which are applicable to research in biology. The MUNSELL BOOK OF COLOR is applicable to general color description and the SOIL COLOR CHARTS, because of their color range and detail, are especially suitable for mammalogy.

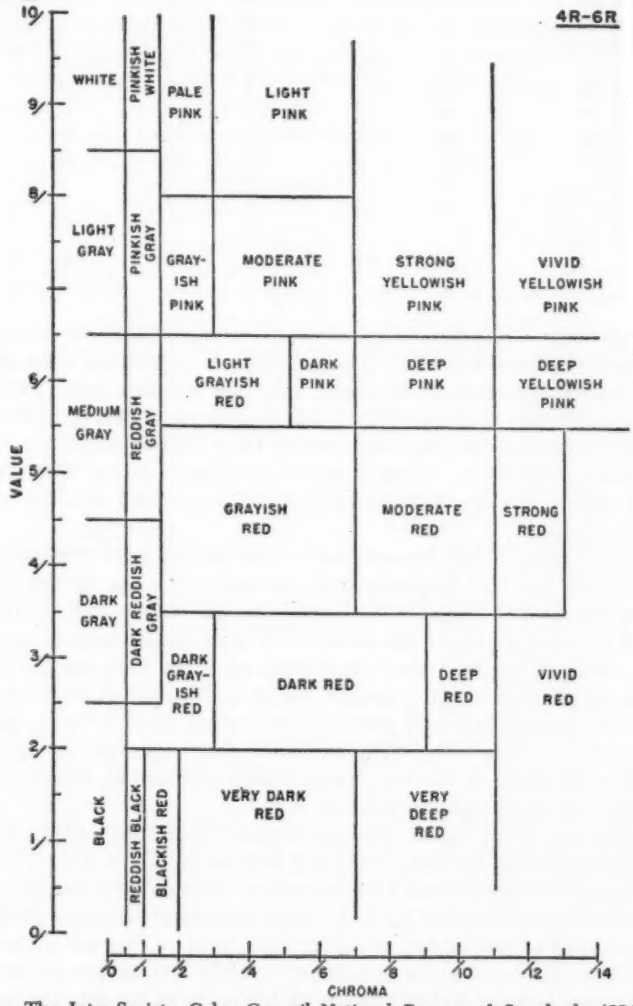


FIG. 2.—The Inter-Society Color Council–National Bureau of Standards (ISCC-NBS) method of color designation in conjunction with the Munsell notations for hues 4R-6R. *(Reproduced by permission of the Munsell Color Company, Inc.).*

TABLE 1.—*Hue distribution of colors cited by Hall (1946) and Durrant (1952) in mammal descriptions*

MUNSELL HUE	HALL, 1946		DURRANT, 1952		TOTAL	
	Number	Occurrence	Number	Occurrence	Number	Occurrence
7.5 PB			2	4	2	4
5.0 RP			1	1	1	1
2.5 R			1	1	1	1
10.0 R	5	43	8	99	9	142
2.5 YR	3	7	8	16	8	23
5.0 YR	10	39	11	59	14	98
7.5 YR	19	79	20	129	22	208
10.0 YR	17	65	24	206	23	271
2.5 Y	2	3	5	14	5	17
5.0 Y	6	25	6	27	7	52
7.5 Y			2	3	2	3
Total	62	261	88	559	94	820

Book of Color.—The Munsell BOOK OF COLOR is published in four editions, all of which display colors of 40 hues but differ in format and color-chip size. The Pocket Edition contains 42 charts, 958 color samples, and a total of 948 different colors; the Opposite Hues Edition contains 20 charts, 1236 samples, and 1084 different colors; the Neighboring Hues Edition displays a different arrangement of the same samples and colors shown in the Opposite Hues Edition; and the Library Edition displays 58 charts, 2365 samples, and 1078 different colors.

Soil Color Charts.—The Munsell SOIL COLOR CHARTS were developed in cooperation with the U.S. Department of Agriculture for use by the Soil Conservation Service and consist of 7 charts (hues 10R, 2.5YR, 5YR, 7.5YR, 10YR, 2.5Y and 5Y) and a total of 196 colors. The color chips measure ½ × ⅝ in. and are mounted on gray cover stock with apertures between the colors to facilitate comparison with the sample specimen. The charts are contained in a serviceable ring binder and protected by acetate interleaves, so that these features and their size (4¼ × 7¼ in.) make them especially useful for field work. The hue range of the SOIL COLOR CHARTS is shown by the crosshatched area in the hue circle illustrated in Fig. 1.

Using the key of equivalent notations prepared by Hamly (1949), the Ridgway color names used by Hall (1946) and Durrant (1952) in their descriptions of the mammals of Nevada and Utah were given Munsell notations and grouped according to hue as shown in Table 1. These data show that all of the 62 Ridgway colors used by Hall and 82 of the 88 colors used by Durrant are within the range of hues displayed in the SOIL COLOR CHARTS. The frequency occurrence of these colors is illustrated in Fig. 3 with the range of the SOIL COLOR CHARTS indicated by crosshatching. Of the 820 color citations, 98.9 per cent are within the range of hues displayed by the charts.

Hamly (1949) has remarked that biologists find low-chroma colors especially useful and it is interesting to note that only two of the colors used by Hall (1946) and Durrant (1952) have higher chroma than those in the charts (e.g., above /8) and most of the colors are in the low-chroma range between /0 and /6. The colors were fairly evenly distributed in value between 2/ and 9.

Since these data only apply to western mammals, there is no assurance that the color range of these charts would be adequate for all taxonomic groups or geographical areas. The color descriptions given by Durrant (1952) for the Abert squirrel, red squirrel and red-backed mouse, for example, include hues

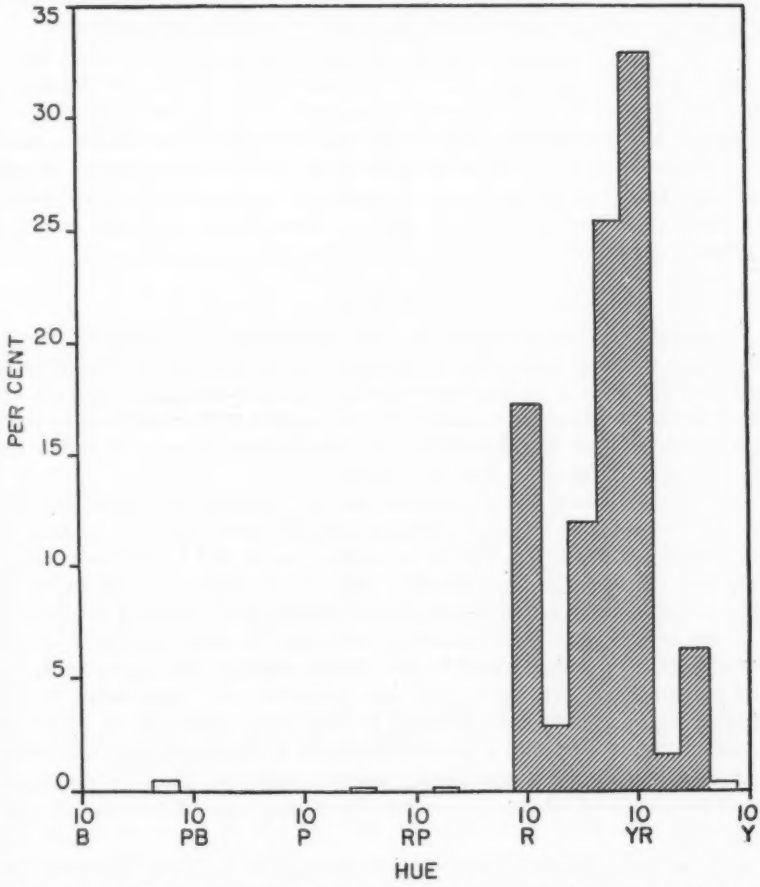


FIG. 3.—Per cent occurrence of 820 color citations used by Hall (1946) and Durrant (1952). Hue range of SOIL COLOR CHARTS indicated by crosshatching.

well outside the range of the charts, but the author has also found that some rather large taxonomic groups such as the Geomyidae may be covered by only a few hues, so that the charts may be entirely adequate for work in certain areas or taxonomic groups.

Disc colorimetry.—The disc-spinning method of colorimetry is simple and accurate and readily adaptable to a wide variety of special problems (Bowers, 1956). An important advantage of the Munsell method is that colorimetric data can be converted from one system to another and can be expressed in terms of numerical notations and/or color names. Since the C.I.E. system is the internationally accepted system of color specification, it is particularly important that colors and color designations be convertible to this system, which is possible with the data derived from any of the Munsell methods.

In the Munsell adaptation of the disc-spinning principle, the discs have a radical slit extending from a center perforation to the outer edge of the disc, so that two or more discs can be interwoven with a portion of each remaining visible. When the discs are spun rapidly with a hand-spinning device or motor they appear as a single color determined by the relative amounts of each disc exposed. With this method it is possible to measure colors to the nearest 0.1 hue step, 0.01 value, and 0.1 chroma. Chromaticity diagrams and work sheets are provided for converting disc mixtures to color notations.

DISCUSSION

A satisfactory color standard must be guaranteed for technical accuracy; the colors must be reasonably permanent; the production method must be such that the colors can be accurately reproduced in successive editions; and there should be adequate assurance that the system will continue to be available as long as there is a demand for it. These criteria seem to be fulfilled by the Munsell System more than by others.

Davis (1956) notes that the authors and publishers of the Maerz and Paul DICTIONARY OF COLOR "expressly disclaim absolute standardization among different copies of the book." The DICTIONARY OF COLOR and Villalobos ATLAS are produced by screen-process printing and are consequently subject to the inaccuracies inherent in this method of color reproduction; it would be especially difficult to guarantee standardization with age in colors produced by this method, since the colors would be affected by aging of the paper stock, and it is not surprising that the authors and publishers are conservative in their claims. Munsell colors are produced in large paint color sheets which are periodically measured with a spectrophotometer to determine their compliance with color specifications and change in color with age. Photometric records taken over a period of years guarantee the permanence of the Munsell color standards.

Color reproduction with opaque paints is considerably more expensive than with screen-process printing and the cost of the Munsell color charts is correspondingly greater than those produced by the latter method, but there is no

alternative if a high degree of technical accuracy and permanent colors are required.

An apparent disadvantage of the Munsell BOOK OF COLOR is that it contains fewer colors than do other systems, so that it is therefore necessary to interpolate more often between color samples. However, absolute color matching is seldom possible with color charts in any event, and the feature of equal visual distance between colors in the Munsell System allows more accurate interpolation. Disc colorimetry can be used and the results expressed in exactly the same terms when absolute color matching is required.

Obviously the needs and preferences of different workers vary according to the nature of their particular research, and certain color systems may seem more attractive than others, but a universally acceptable color standard does seem a desirable aim in view of the useful role that Ridgway's COLOR STANDARDS has had in the standardization of color descriptions and terms in biology. While it is doubtful that Ridgway's COLOR STANDARDS will be completely discarded and a new standard adopted in the near future, certain features of the Munsell System make it particularly adaptable to scientific work and worth consideration.

SUMMARY

The decreasing value of Ridgway's COLOR STANDARDS AND COLOR NOMENCLATURE suggests the need for a new color standard in biology. Of the available color chart systems, the Munsell System of Color Notation seems to offer a high standard of technical accuracy and the greatest adaptability to particular research problems. The principal feature of this system is a method of color notation in which three visual color attributes of hue, value and chorma are arranged in scales of equal visual distance that are valid for any normal observer. Although the color notations in this system are expressed numerically, the use of color names is also provided for by the ISCC-NBS method of color designation in conjunction with the appropriate Munsell notation. The Munsell Color Company, Inc. produces a variety of color-reference materials of which the BOOK OF COLOR, SOIL COLOR CHARTS, and disc colorimetry method are particularly applicable to color problems in biology.

LITERATURE CITED

BOWERS, D. E. 1956. Methods of color determination. Syst. Zool., 5: 147–160, 182.

DAVIS, J. A., JR. 1956. A plea for an adequate color standard. Jour. Mamm., 37: 269–271.

DURHAM, F. E. 1941. A reflectometer for measuring colors of animals. Jour. Mamm., 22: 199–201.

DURRANT, S. D. 1952. The mammals of Utah. Univ. Kansas Publ., Mus. Nat. Hist., 6:1–549.

FOSS, C. E. 1949. Color-order systems. Jour. SMPE, 52: 184–196.

HALL, E. R. 1946. The mammals of Nevada. Univ. Calif. Press, Berkeley and Los Angeles. 710 pp.

HAMLY, D. H. 1949. The Ridgway color standards with a Munsell notation key. Jour. Optical Soc. Amer., 39: 592–599.

ILLMAN, W. I. AND D. H. HAMLY. 1948. A report on the Ridgway color standards. Science, 107: 626–628.

MAERZ, A. AND M. R. PAUL. 1950. A dictionary of color. 2d ed. McGraw-Hill Book Co., N.Y. 206 pp., 53 pl.

MUNSELL. 1942. Book of color. Library ed. Munsell Color Co., Baltimore. 2 vol., 58 pl.

———. 1950. Book of color. Neighboring Hues ed. Munsell Color Co., Baltimore. 20 pl.
———. 1950. Book of color. Opposite Hues ed. Munsell Color Co., Baltimore. 20 pl.
———. 1942. Book of color. Pocket ed. Munsell Color Co., Baltimore. 2 vol., 42 pl.
———. 1954. Soil color charts. 3d ed. Munsell Color Co., Baltimore. 7 pl.
NICKERSON, D. 1956. A review of "The ISCC-NBS method of designating colors and a dictionary of color names." Science, 123: 678–679.
RIDGWAY, R. 1912. Color standards and color nomenclature. A. Hoen, Washington. 44 pp., 53 pl.
SUMNER, F. B. 1927. Linear and colorimeteric measurements of small mammals. Jour. Mamm., 8: 177–206.
VILLALOBOS-DOMINGUEZ, C. AND J. VILLALOBOS. 1947. Atlas de los colores. El Ateneo, Buenos Aires. xv + 74 pp., 38 pl.

Experiment Station, Colorado State Univ., Ft. Collins. Received December 17, 1956.

AN IMPROVED LIVE TRAP FOR SMALL MAMMALS

By JOSEPH P. LOBUE AND REZNEAT M. DARNELL

A number of live traps have been described in recent literature for the capture of small mammals. These may conveniently be classified as single- and multiple-capture traps. In the single-capture traps the door is usually open in the set trap, and it is closed and locked automatically by the entering animal. This is normally accomplished by means of a treadle, false floor, or bait-tripping lever, and the door may be operated either by a spring or by gravitational force. While single-capture traps are generally effective in retaining the entering animals, they are prone to mechanical failure, and the complexity of the trapping mechanism may lead to the death of the captive animal (see Burt, 1940). This type of trap is also expensive and delicate of construction. In addition, the single-capture trap is subject to theoretical objections in population studies where the possibility of multiple captures is an important consideration, e.g., home range studies.

Multiple-capture traps are so constructed that the door does not lock after the first animal enters, and hence more than one animal may theoretically be obtained at a single setting. This type of trap, while of simple construction, also has certain disadvantages. Animals frequently are able to escape, and the presence of one animal in the trap may encourage or discourage the entrance of other individuals.

The trap described in the present paper is designed to eliminate certain objectionable features of the above types of traps. Essentially, the new trap is a modification of the standard wooden multiple-capture trap used by Gunderson (1950), embodying the following features. (1) The new trap is longer than usual and, weighing 16 ounces, it is 25–50 per cent heavier than most standard traps (see Chitty and Kempson, 1949). (2) The new trap is essentially a trap within a trap, incorporating a middle swinging door which separates the interior into anterior and posterior chambers. (3) Above the front

door there is placed a window, of galvanized sheet metal, which has been punched with holes for ventilation. (4) Windows, covered with hardware cloth, have been placed on each side of the posterior chamber to permit ventilation of that area. (5) The back door, which allows the investigator access to the posterior chamber, is composed of heavy aluminum sheeting which slides in lateral grooves and which locks into a groove in the floor of the trap. (6) A metal plate is affixed to the ceiling of the posterior chamber to prevent gnawing and escape at the point where the back door meets the ceiling (Fig. 1).

Assumptions leading to the design of the trap are as follows. An animal which finds itself in the anterior chamber is faced with two alternative apparent escape routes, the window above the front door and the middle door. Becoming frustrated in attempts to escape through the window, the animal is essentially forced to pass through the middle door. Finding itself in the posterior chamber the animal is faced with a single apparent escape route, i.e., the windows located at the back end of the posterior chamber. Hence, if the above assumptions are correct, only a small fraction of the individuals which enter the anterior chamber should escape through the front door and, likewise, only

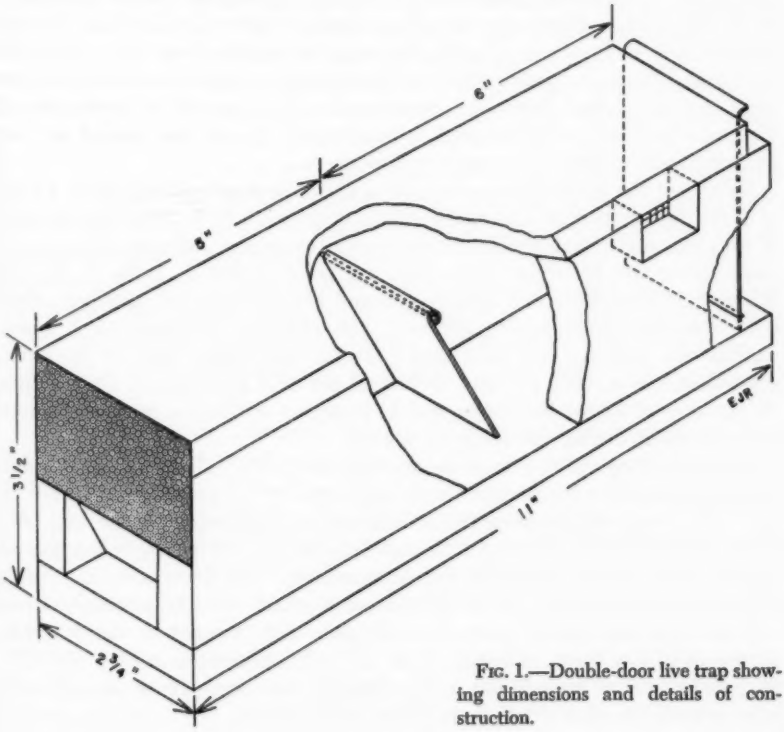


FIG. 1.—Double-door live trap showing dimensions and details of construction.

TABLE 1.—*Trapping efficiency of the acclimated traps (July 26 to August 8, 1956). Only data for the two primary species are given. In addition, captures of Zapus hudsonius (T=299) and of Citellus tridecemlineatus (T=371) were obtained*

SPECIES	NUMBER OF TRAPNIGHTS	NUMBER OF CAPTURES	TRAPPING EFFICIENCY	
			Number of mice per trapnight (M)	Number of trapnights per mouse (T)
P. maniculatus	4,080	168	0.041	24.3
M. pennsylvanicus	4,080	239	0.059	17.0

a small fraction of those individuals which reach the posterior chamber should pass back into the anterior chamber where they would still be held. Since most individuals entering the trap would be expected to settle eventually in the posterior chamber, their presence in the trap should theoretically have little influence upon the entrance of other individuals.

The efficiency of the new trap was tested in a preliminary field study conducted on an alfalfa field near Cedarburg, Wisconsin. In this study, 255 of the double-door traps were placed in a grid at intervals of 30 feet. During the first four days of trapping the frequency of captures was low. Since this appeared, obviously, to be related to the unnatural odors associated with the traps, the initial four days were considered to be a period of acclimation of the traps to field conditions, and data obtained during this period are not included in calculation of trapping efficiency.

Following the acclimation period the traps were set for 16 nights or a total of 4,080 trapnights during the period July 26 to August 18, 1956. The number of captures and trapping efficiencies for the two primary species, *Peromyscus maniculatus* and *Microtus pennsylvanicus*, are recorded in Table 1. During this period 168 captures of *P. maniculatus* and 239 captures of *M. pennsylvanicus* were obtained (including recaptures). The trapping efficiency for *P. maniculatus* was 0.41 (or one individual per 24.3 trapnights) and for *M. pennsylvanicus* it was 0.059 (or one individual per 17.0 trapnights). In addition, 15 captures of *Zapus hudsonius* and 11 captures of *Citellus tridecemlineatus* were obtained during the trapping period.

Data regarding multiple captures are included in Table 2. A pair of *P. maniculatus* appeared in the trap five times and a pair of *M. pennsylvanicus* eleven times. *P. maniculatus* was captured with *M. pennsylvanicus* in one case, and *P. maniculatus* occurred with *C. tridecemlineatus* once (in this case the ground squirrel had largely consumed the deer mouse). On three occasions triple captures were obtained, and all individuals involved were *M. pennsylvanicus*.

In most of the above cases all individuals were located in the posterior chambers of the traps, although 7 (of 168) *P. maniculatus* and 4 (of 239) *M. pennsylvanicus* were found in the anterior chambers. These animals may have entered the traps shortly before they were tended.

TABLE 2.—*Frequency of multiple captures. Period of trapping and total trapnights are given in Table 1*

NUMBER IN TRAP	OCCURRENCE	SPECIES INVOLVED
2	11	*M. pennsylvanicus* (alone)
2	5	*P. maniculatus* (alone)
2	1	*P. maniculatus—M. pennsylvanicus*
2	1	*P. maniculatus—C. tridecemlineatus*
3	3	*M. pennsylvanicus* (alone)

During the field trials certain general advantages of the double-door trap were noted. (1) Being of wooden (redwood) construction, the trap provided insulation against thermal changes. (2) The floor groove effectively prevented captives from raising the back door and escaping by that route. (3) Since most captives were found in the posterior chamber their removal from the trap was greatly facilitated. (4) The windows in the rear of the posterior chamber, in addition to supplying ventilation, also permitted entrance of large numbers of small invertebrates (field insects and small gastropods). These supplied the captive rodents with an abundance of natural food.

Certain disadvantages of the double-door traps were encountered during the field trials. (1) Since two chambers are involved, baiting and tending required considerable time. (2) The trap was not easily cleaned in the field. However, removal of most of the old bait and drying of the traps on stakes during the intervals between settings was found to prevent serious mold growth and fouling. (3) As indicated above, small invertebrates found ready access to the posterior chamber, and for this reason mammals taken in the trap should not be used for food studies. (4) Before metal plates were affixed to the ceiling of the posterior chamber, an estimated 13 *M. pennsylvanicus* escaped by gnawing through at that point. This susceptibility to gnawing appears to be a disadvantage of wooden traps in general (see Manville, 1949; Gunderson, 1950).

The double-door trap is somewhat larger and more burdensome than standard single-door traps and requires more time to tend. In common with all wooden traps it is well insulated, resulting in higher survival of captives, and escape by gnawing must be prevented by proper placement of metal sheeting at vulnerable locations. However, the double-door trap is relatively uncomplex and hence inexpensive and rather simple to construct, tend and maintain. The unique feature of the trap is its ability to hold individuals which enter and to allow accumulation of several individuals simultaneously in a given trap.

Thanks are hereby expressed to Mr. Erwin Frank of Cedarburg, Wisconsin, for the many courtesies and facilities rendered during the course of the present study.

LITERATURE CITED

BURT, WILLIAM H. 1940. Territorial behavior and populations of some small mammals in southern Michigan. Mus. Zool. Univ. Mich., Misc. Publ. 45: 1–58.

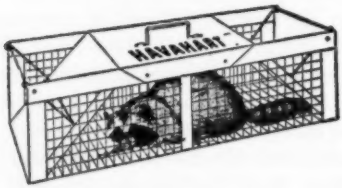
CHITTY, DENNIS AND D. A. KEMPSON. 1949. Prebaiting small mammals and a new design of live trap. Ecology, 30: 536–542.

GUNDERSON, HARVEY L. 1950. A study of some small mammal populations at Cedar Creek Forest, Anoka County, Minnesota. Minn. Mus. Nat. Hist. Occ. Papers, 4: 1–49.

MANVILLE, RICHARD H. 1949. A study of small mammal populations in northern Michigan. Mus. Zool. Univ. Mich., Misc. Publ. 73: 1–83.

Dept. of Biology, Marquette Univ., Milwaukee 3, Wisconsin. Received February 8, 1957.

HAVAHART HUMANE ANIMAL TRAPS



The *Allcock Manufacturing Company* has a large variety of humane animal traps. They have many sizes of live traps for those who are interested in catching the animals unharmed. The HAVAHART TRAPPING BOOKLET will be sent free of charge to anyone who requests it from the *Allcock Manufacturing Company, Ossining, New York.* HAVAHART traps have been used successfully by many who have been doing live-trapping experiments on small mammals. Write for the free booklet today.

GLEANINGS FROM THE FIELD

On a year's sabbatical leave from Georgia, Eugene P. Odum is traveling to various A.E.C. projects on the west coast. Arthur Svihla is visiting in New Zealand and Australia. W. Leslie Robinette, of the Fish & Wildlife Service, has recently transferred from the Salt Lake City to the Denver office. And who questions that our winters are getting milder? From Kodiak, Alaska, Kim Clark writes that "There has been enough snow for skiing only two days; it has been raining ever since."

GENERAL NOTES

SOME DISTRIBUTION RECORDS OF MAMMALS FROM HUDSON BAY

In August, 1953, I was privileged to visit several islands in Hudson Bay. Below, I wish to report a few occurrences that fill in some of the gaps in the known distribution of land mammals of that area.

The collared lemming (*Dicrostonyx hudsonius*) has been known from the Belcher Islands, Christie Island (in the Nastapoka Islands), and Digges Island, Port LaPerriere (Anderson and Rand, Jour. Mamm., 26: 303, 1945). I took specimens on Renouf Island, at the north end of the Belcher Islands; on Johnson Island, in the North Belcher Islands group; and on Elsie Island, near the Ungava Coast northwest of Port Harrison, Lat. 58° 50′ N. Lemming sign was seen at the north end of Flaherty Island and on an unnamed island at the extreme north of the North Belcher Islands. On most of the islands, the lemmings apparently nested in the rocks and foraged in the small tundra meadows. There were numerous dead-end burrows, one to two feet in length, in the meadows where there was a little soil, but these, I suspect, were primarily refuge burrows. The several that were dug out were unoccupied. Lemmings were active during the day.

Nests of the previous winter, about eight inches in diameter and above ground, were still in good condition in August. Also, there were accumulations of feces, a pint or more in a place. The individual pellets are less than half the size of those of *Microtus*. They are voided, in the manner of deer pellets, not singly.

The meadow vole (*Microtus pennsylvanicus*) was taken on a small unnamed island near the mouth of Richmond Gulf. Here, they were living in rock piles on a beach. They were extremely numerous. We caught several with our hands by turning over rocks. Two or three individuals under a rock 15 inches in diameter was usual.

A nearly complete skeleton of a least weasel (*Mustela rixosa*) was recovered from an owl pellet picked up on Elsie Island. This species is known from both north and south of here so its occurrence was to be expected. Also, a partial skeleton of the Arctic hare (*Lepus arcticus*) was picked up on Elsie Island.—William H. Burt, *Museum of Zoology, University of Michigan, Ann Arbor.* *Received April 6, 1957.*

NEW MAMMAL RECORDS FOR PRINCE EDWARD ISLAND

Subsequent to the publication of a report on the mammals of Prince Edward Island (Bull. Nat. Mus. Can., No. 126: 185–194, 1952) based on specimens in various museum collections, the writer visited the Island for a three-month period in 1954. A number of species were definitely added to the faunal list, and while these will be published in a forthcoming memoir of the Canadian Museum of Natural History (Mammals of the Islands in the Gulf of St. Lawrence), it seems well to place on record at this time a list of the species previously unrecorded. The following have been definitely added to the list of the island's mammals, and are supported by specimens in the Canadian Museum of Natural History collection unless otherwise noted:

Sorex fumeus umbrosus Jackson.—A female was taken on June 5, 1954, at Fortune, Kings County, 2 mi. W Souris. Skin and skull.

Glaucomys sabrinus gouldi Anderson.—A male was trapped on June 2, and a female on July 12, 1954, at Rollo Bay, Kings County, 3 mi. W Souris. The male consists of skin and skull and the female of skull only. Local residents report that this species is uncommon, which is probably understandable since less than 20 per cent of the land area of the island is wooded.

Napaeozapus insignis insignis (Miller).—Two males were taken at Fortune, Kings County, 2 mi. W Souris, one on June 4 and the other on June 9, 1954. Both specimens have skin and skull.

Mustela erminea richardsoni Bonaparte.—Although the ermine is not uncommon on the island, specimens do not appear to have found their way into collections and distributional maps generally indicate its absence on the Island. A female was taken on July 11, 1954, at Rollo Bay, Kings County, 3 mi. W Souris. Unfortunately, the specimen could not be preserved.

In addition to the above species, the following terrestrial mammals have been recorded from the island: *Sorex cinereus, Microsorex hoyi, Blarina brevicauda, Myotis lucifugus, Lepus americanus, Tamias striatus, Tamiasciurus hudsonicus, Castor canadensis* (original population extirpated), *Peromyscus maniculatus, Clethrionomys gapperi, Microtus pennsylvanicus, Ondatra zibethica, Rattus norvegicus, Mus musculus, Zapus hudsonius, Vulpes fulva, Ursus americanus* (extirpated), *Procyon lotor* (introduced), *Mustela vison, Mephitis mephitis* (introduced), *Lutra canadensis, Lynx canadensis* (extirpated), and *Odocoileus virginianus* (introduced).—Austin W. Cameron, *Canadian Museum of Natural History, Ottawa, Ontario. Received March 7, 1957.*

A RECORD OF *SOREX ARCTICUS* FOR NEW BRUNSWICK

Although there are two published records of the saddle-backed shrew, *Sorex arcticus*, in New Brunswick, neither seems to be supported by extant specimens, and it therefore seems desirable to place on record the recent acquisition, by the Canadian Museum of Natural History, of a specimen collected near Sackville in 1949. Cox in 1896 (Bull. Nat. Hist. Soc., N.B., 14: 53–55) reported, without details that a specimen of *Sorex richardsoni* [*arcticus*] was collected by him at Maugerville, Sunbury County. Strangely, he stated that this species was "common in intervales and low wet woodlands" adjacent to the Saint John River. Subsequent collecting in the province has not shown this to be true in recent years. It is therefore unfortunate that he failed to give at least a brief description of his specimen as confusion with other species is not impossible.

Morris (Jour. Mamm., 29: 165–176) stated that a specimen of *arcticus* was collected at Hampden, Kings County, by H. E. Hill. He did not state whether the specimen was preserved or, if so, its present whereabouts.

The present specimen, consisting of skin only, was secured by George F. Boyer of Sackville, New Brunswick, on July 7, 1949, at Front Lake, Jolicure, Westmoreland County, 6 mi. NE Sackville. It has the following measurements: total length, 116; tail, 40; hind foot, 14 mm. In view of its generally pale coloration, particularly on the sides, it is probably referable to *maritimensis*, the race occurring in Nova Scotia.

The occurrence of this species in New Brunswick is not surprising since it has been taken in Nova Scotia to the east and Quebec to the west. It is remarkable, however, that to date so few specimens have been taken in New Brunswick.—Austin W. Cameron, *Canadian Museum of Natural History, Ottawa, Ontario. Received March 9, 1957.*

A RECORD OF HOMING IN THE BIG BROWN BAT

During the springs of 1955 and 1956, nine big brown bats, *Eptesicus fuscus*, were banded and released on the campus of the University of Illinois, Urbana. These bats had all been taken from their hibernating quarters in Blackball Mine, 1¾ mi. W Utica, LaSalle Co., Ill., which is an airline distance of 95 mi. NNW Urbana. Two of these bats have since been retaken in Blackball Mine. A female (No. 57-03530) taken in February, 1956, and released May 6, 1956, after being kept in captivity at Urbana, was recovered at Blackball Mine on January 26, 1957. Another female (No. 57-02804) taken on February 28, 1955, and released at Urbana on June 1, 1955, was retaken at the Mine on February 16, 1957. These records establish a homing ability not previously known for this species. It has formerly been known to return from as far as 60 miles (Tibbetts, The Southwestern Nat., 1: 194, 1956).—John S. Hall and Wayne H. Davis, *Museum of Natural History, Univ. of Illinois, Urbana. Received March 15, 1957.*

TADARIDA FEMOROSACCA AND *TADARIDA MOLOSSA* AT CARLSBAD CAVERNS, NEW MEXICO

Recent bat rabies investigations by the Communicable Disease Center at Carlsbad Caverns National Park have produced the new locality records reported herein. These bats were captured by a bat trap as they flew through the main entrance of Carlsbad Cavern. The trap also captured over 45,000 *Tadarida brasiliensis mexicana* (Saussure) during parts of May, August, September, October and November, 1956, when the trap was in use. New records are as follows:

Tadarida femorosacca (Merriam). Pocketed freetail bat.—A lactating adult female pocketed freetail bat was found in the bat trap September 8, 1956. This is the northeasternmost record for the species, extending the range approximately 354 mi. ENE from Ft. Huachuca, Cochise Co., Arizona (Shamel, Proc. U.S. Nat. Mus., 78, (19): 1–27, 1931) and some 740 mi. NW from 10 km. NNE Antiguo Morelos, Tamaulipas, Mexico (Dalquest and Hall, Univ. of Kans. Publ. Mus. Nat. Hist., 1, (13): 245–248, 1947).

Tadarida molossa (Pallas). Big freetail bat.—An immature female big freetail bat was found in the bat trap October 10, 1956. This record fills a gap in the known range (Miller and Kellogg, U.S. Nat. Mus. Bull. 205, 1955) and is the first record for New Mexico.—DENNY G. CONSTANTINE, *Communicable Disease Center, U.S. Public Health Service, Carlsbad, New Mexico. Received March 5, 1957.*

CHILONYCTERIS PSILOTIS IN SAN LUIS POTOSÍ, MEXICO

Recent bat rabies investigations in the state of San Luis Potosí, Mexico, necessitated trapping bats as they departed from a cave on Rancho Nacimiento del Rio Coy, 16 mi. S Valles. At 5:30 PM, January 23, 1957, a bat trap was installed in the cave entrance and the trap was observed and bats removed at half-hour intervals until 11:30 PM. The following estimated numbers of bats were captured, primarily during the time periods indicated: 100 *Chilonycteris psilotis Dobson*, 6:30–8:30; 400 *Chilonycteris rubiginosa mexicana* Miller, 6:30–7:40; 100 *Pteronotus davyi fulvus* (Thomas), 6:30–7:40; 600 *Mormoops megalophylla senicula Rehn*, 6:30–9:00; 10 *Artibeus jamaicensis jamaicensis* Leach, 7:30–11:00; 150 *Natalus mexicanus saturatus* Dalquest and Hall, 9:00–11:30 15 *Glossophaga soricina leachii* (Gray), 9:00–10:30; 50 *Desmodus rotundus murinus* Wagner, 9:00–11:30. All vampires and a few examples of each species were retained, the remaining bats being released soon after capture.

Dalquest and Hall (Jour. Mamm., 30:425) reported the previous northernmost locality record for *Chilonycteris personata* Wagner (*Chilonycteris psilotis* Dobson according to de la Torre, Fieldiana: Zool., 37: 695–701) at Tuxtla Mountains, 3 km. E San Andrés Tuxtla, Veracruz, Mexico. The new record extends the known range some 330 miles northwestward on the east coast of Mexico. One female and six males were selected at random and retained. Grateful acknowledgment is extended to William B. Davis for confirming identification of these specimens.—DENNY G. CONSTANTINE, *Communicable Disease Center, U.S. Public Health Service, Carlsbad, New Mexico. Received March 5, 1957.*

NOTES ON A BREEDING COLONY OF *MYOTIS*

Published studies on the little brown bat, *Myotis l. lucifugus*, such as those of Stegeman (Jour. Mamm., 35: 111–113, 432–433, 1954), Griffin (Jour. Mamm., 21: 181–187, 1940), Smith (Ohio Jour. Sci., 54 (1): 1–12, 1954) and others, leave unanswered many questions about the life of this bat. The following observations were made in a large breeding colony of this species.

These data were secured at a building known as the Old Stone Fort, in the village of Schoharie, Schoharie County, New York. The authors wish to express their gratitude to Myron C. Vrooman, curator, who permitted access to the building and assisted us in our collecting. Identifications of ectoparasites were made by Helen Sollers and E. W. Baker.

The building is used by bats only in the summer, when it serves as a nursery. At this time, the attic and belfry are occupied by hundreds of little brown bats. Griffin (Jour. Mamm., 26: 14–23, 1945) banded bats here and estimated the population of the colony at about 200 individuals. In late July, 1955, when our collections were made, we estimated that about 1,000 individuals were occupying the building. Since the Fort is a tourist attraction, and a colony of such magnitude is accompanied by a considerable stench, these bats constitute a nuisance. We were therefore permitted to collect as many specimens as possible before efforts were made to eliminate or drive out the colony.

On July 22, we collected 120 specimens. A second collection, on July 30, numbered 50 specimens. In each case, the collection included a small portion of the number observed, for the attic and belfry offer abundant hiding places where the bats are irretrievable. Both collections were made in the same manner, by hand or with forceps. A few bats were caught in flight with insect nets. The bats were chloroformed at once, and removed to a freezer locker. During the week following collection, they were removed from the freezer and weights, measurements and other data were recorded. Since previous experience has shown that mammals packaged in plastic freezer bags lose no weight by dehydration, it is believed that this procedure did not affect the data in any way.

All measurements were made by the junior author, to insure uniformity. Age was determined by color of the pelage, size and weight, development of the joints of the wing-bones, and in questionable cases by examination of the mammary glands and reproductive tract. No adult males were present in the colony, so that aging problems arose only in connection with small adult females and the largest immature females.

The ratio of young to adults in summer colonies of this species would be expected to be about 1:1, since females normally give birth to one young. Stegeman (*op. cit.*, 432) reported nearly three adult females for each young in a colony at Newcomb, about 100 miles north of the Schoharie colony. This colony was sampled in the same manner used in our study, although his collections were made somewhat earlier (July 15). In another study (*op. cit.*, 111) he found 235 young and 297 adult females in a colony on July 15; discrepancy from a 1:1 ratio might be ascribed to juvenile mortality, or to non-breeding adult females in the colony, if age determination was accurate.

In the Schoharie colony, the ratio of young to adult in our collections was 1.74:1 (108 young, 62 adults). This disagrees sharply with Stegeman's data on specimens collected in the same manner. Since our collections were one and two weeks later than Stegeman's, this suggests that females, after nursing duties are ended, may leave the colony at an earlier date than the young. This possibility is supported by the fact that the young to adult ratio on July 22 was 1.55:1, and in the July 30 collection, 2.33:1. Our collections, however, are not sufficiently large to render this difference highly significant.

The sex ratio among immatures was almost exactly the expected 1:1. We collected 55 males and 53 females, a ratio of 1.04:1. This figure, incidentally, served to strengthen our belief that age determination was almost completely accurate.

In his study of 532 specimens, Stegeman reported a parturition period extending from May 23 to July 14. The latter date was precisely determined, since he took one specimen which was only a day or two old. In the Schoharie colony, however, we collected no bats smaller than 5 grams in weight. Applying the technique by which Stegeman calculated age of young, the smallest bat was born about June 10 and the beginning of the parturition period, based on the largest immatures, was about May 20. It is possible that smaller young were present, hidden in more secure recesses than the larger bats, but there is no evidence that this was true. The last week in May appears to represent the high point of the parturition period in this colony. About 80 per cent of the immatures collected fell into this age group.

Analysis of the data, as presented in Fig. 1, indicates that adult females of this species in midsummer weigh from 7.5 to 10.5 grams, with most individuals weighing 8–9 grams. By this time (late July) the largest immatures weigh about 8 grams. No size criterion was

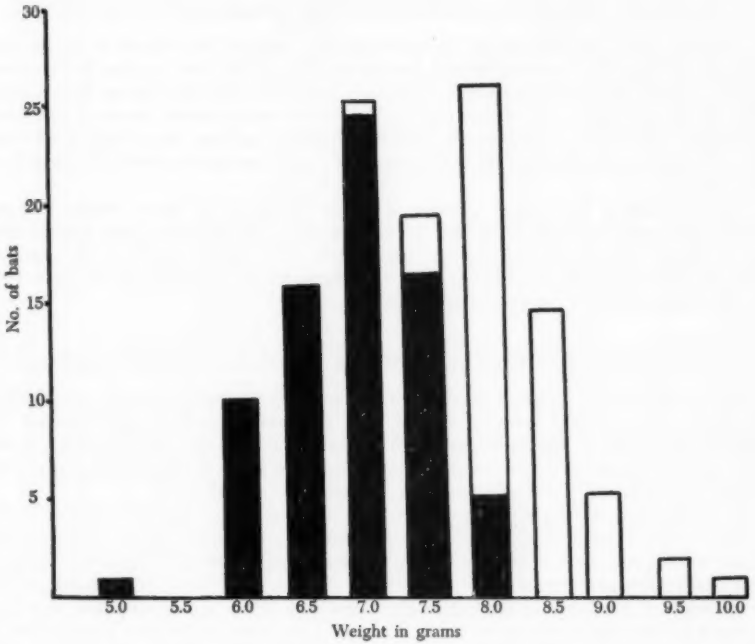


FIG. 1.—Age and weight of 120 little brown bats collected on July 22, 1955. Solid area indicates immatures, open area indicates adults.

found to be of any value in separating young of the year in this weight group from adults. Forearm length of adults which had undoubtedly borne young varied from 35 to 41mm., and most of the immatures had forearms within this size range. Total length was equally unreliable. Stegeman judged metacarpal length to be a relatively reliable criterion of age, but measurement of our specimens showed that this was of no value in determining age of the critical group which weighed 7–8 grams. In almost every case, however, the development of the mammary glands and the size of the uterus indicated clearly whether parturition had occurred. The presence of non-breeding adult females might cause some error, if such individuals are present in nursery colonies.

Bats in this colony were heavily parasitized. Large numbers of fleas, *Myodopsylla insignis*, were removed from the chloroformed specimens and others were seen on the beams. Small mites of the genus *Spinturnix* were abundant on the wing membranes of some bats but none were found in the fur. A few well-attached ticks (*Ornithodoros* sp.) were taken. One bedbug was seen, but escaped collection.

Occurrence of a late summer molt was indicated by the fact that all adults were in some stage of molting. Most of the immatures, of course, were also molting, though the largest were in pelage which could not be distinguished from the adults.—ALLEN H. BENTON AND JACK SCHAROUN, *New York State College for Teachers, Albany.* *Received March 6, 1957.*

ANOTHER WISCONSIN RECORD OF THE PRAIRIE SPOTTED SKUNK

The first prairie spotted skunk, *Spilogale putorius*, reported for Wisconsin (Scott, Jour. Mamm., 32:363, 1951) was captured November 19, 1946, in St. Croix County. In November, 1955, a second specimen was taken in Jefferson County near Fort Atkinson by Robert Ward. The skunk was caught with a steel trap at the entrance to its burrow in an old milkhouse. Attempts were made to catch another individual with a box trap when fresh tracks were found in the same area; from all indications, this animal vacated the area after setting off the trap.

Measurements of the trapped specimen, a female (UWZ-14770) were: weight, 872 gm.; total length, 620; tail, 290; hind foot, 50; ear, 30 mm. The following skull measurements were taken: condylobasal length, 58; basal length, 52.3; palatal length, 21.3; zygomatic breadth, 37.8; mastoidal breadth, 31.9 mm.—FRANK A. IWEN, *Zoology Dept. Museum, Univ. of Wisconsin, Madison.* *Received July 3, 1957.*

SUBFREEZING BODY TEMPERATURES IN DORMANT GROUND SQUIRRELS

One of the features typical of mammals which normally pass into a seasonal state of deep dormancy is the marked lowering of their body temperature. This usually becomes only slightly above that of the environment. Subsequently, during the actual dormant period, their body temperatures parallel more or less the variations in the environmental temperature. Thus a homeothermic mammal becomes a heterothermic animal.

In the literature, among the many references to this phenomenon, are the works of Dubois (1896), Shaw (1925), Johnson (1931), Suomalainen and Suvanto (1953), among others. These investigators have demonstrated that the body temperature of hibernating mammals while in the dormant state is usually maintained a few degrees C. above the environmental temperature if the latter is above freezing. However, if the surrounding temperature is lowered to freezing or below, the torpid animal may react to this low temperature by awakening. Valentin (1857), Horvath (1881) and Dubois (1896) have stated that awakening always occurs under such conditions. The explanation usually given for this awakening is that by so doing the animal may keep from freezing to death.

Johnson (1929), on the other hand, reported that some but *not all* of his dormant ground squirrels (*Citellus tridecimlineatus*) responded by awakening to near-freezing temperatures. Wade (1930) confirmed Johnson's observations for he too found that some of his dormant ground squirrels awoke as a result of a drop in temperature but that death occurred in others without the animals awakening. Benedict and Lee (1938) found that, in the marmot, death occurred when a rectal temperature of 3°C. was reached. Horvath (1881), however, reported that the body temperature of dormant ziesels varied from –0.2 to 1.8°C. The animal at –0.2°C. awoke because the surrounding temperature had been lowered to –0.5°C. Johnson (1931) questioned the validity of Horvath's records. Eisentraut (1933) recorded temperatures of dormant bats somewhat below 0°C.

Lyman (1948) has shown in the dormant hamster that due to a circulatory shunt the posterior part of the body has a lower temperature than that of the head and thorax and, therefore, the rectal temperature is not such a good criterion for the body temperature as that of the cheek pouch since the latter is similar to that of the heart.

During February and March, 1952, observations and records were made of the body temperatures of dormant ground squirrels (*Citellus undulatus parryi*) at Fairbanks, Alaska. It was our experience that awakening or death did not always occur when the dormant animals were exposed to low environmental temperatures, even if the latter were below freezing.

Using Lyman's technique, we placed thermocouples in the cheek pouches of our experimental animals, in the nest chamber and in an ice-water bath control. The temperatures of these three areas were recorded simultaneously by means of a Brown constant-recording potentiometer.

TABLE 1.—*Temperature data (°F.) on a dormant ground squirrel, 1952*

	FEB. 19	FEB. 29	MARCH 8
Air temp.	+18°	+22°	+15°
Cheek-pouch temp.	+29°	+32°	+29°
Ice-water bath temp.	+32°	+32°	+32°

Of the numerous data obtained, those of one animal on three different occasions extending over a period of 18 days are of particular interest. At no time during this 18-day period did the animal awaken as the result of exposure to low temperatures or to being handled. That the animal was dormant was obvious by its low respiration rate. The data obtained are listed in Table 1.

Thus, on both February 19 and March 8, the cheek-pouch temperatures were 3°F. below freezing while on February 29 the cheek-pouch temperature of the animal was at freezing temperature. The nest-chamber temperature varied on the three occasions from +15 to +22°F. or from 17 to 10°F. below freezing.

In order to check the accuracy of these readings and the sensitivity of the thermocouples, as well as of the recording apparatus, an interchange of thermocouples was made from the ice-water bath and from the nest chamber to the cheek pouch. The records were unchanged.

A possibility of error due to the conduction of the low environmental temperatures into the cheek pouch by the metal sheath surrounding the thermocouple wires was tested by the use of other thermocouples which were unsheathed and placed inside the closed mouth of the animal. Still the same readings were obtained.

I am indebted to Dr. J. MacClure Johnson, of Cornell University, who very kindly checked these readings by using his own thermocouples and a precision Leeds and Northrup double-range portable potentiometer whose maximum error was 0.2°F. He independently obtained the same cheek-pouch temperatures as those recorded above.

These data confirm the observations of Horvath and Eisentraut, that the temperatures of certain mammals in dormancy may normally drop below freezing, as well as those of Johnson and Wade that awakening in ground squirrels does not always occur at temperatures below freezing.

Andjus (1951), Andjus and Smith (1954), and Smith, Lovelock and Parkes (1954) showed that the laboratory rat can be frozen solid at temperatures of –4 to –7°C. and, with proper heart and respiratory stimulation, may be revived without detrimental effects.

Svihla (1955) recorded that dormant ground squirrels are apparently resistant to frostbite and that while these mammals are in the dormant state, below freezing, body temperatures may normally be tolerated without serious injury.

My conclusion from the data recorded above is that, during dormancy, tolerances of the ground squirrel to temperatures at or below freezing are greater than has previously been surmised.

Acknowledgment is hereby made to the Air Force under Contract AF 33(038)-18509 for aid and assistance in carrying out this study.—ARTHUR SVIHLA.

LITERATURE CITED

ANDJUS, R. 1951. Sur la possibilite de ranimer le rat adulte refroid jusqu'a' proximite du point congelation. Comp. Rend. Acad. Sci., 232: 1591–1593.

——— AND A. U. SMITH. 1954. Revival of hypothermic rate after arrest of circulation and respiration. Jour. Physiol., 123: 66–67.

BENEDICT, F. G. AND R. C. LEE. 1938. Hibernation and marmot physiology. Carnegie Inst. Bull. 497: 1–497.

DUBOIS, R. 1896. Physiologie comparee de la marmotte. Annales de l'Universite de Lyon. Paris.

EISENTRAUT, M. 1934. Der Winterschlaf der Fledermäuse mit besonderer Berücksictigung der Wärmeregulation. Ziet. Morph. Ökol. Tierre, 29: 231–267.

HORVATH, A. 1881. Einfluss der verschiedener Temperaturen auf die Winterschläfer. Verh. Ges. Würzb., 25: 187–219.

JOHNSON, G. E. 1929. Hibernation in the thirteen-lined ground squirrel (*Citellus tridecimlineatus*). II, The general process of awakening from hibernation. Amer. Nat., 63: 171–180.

———. 1931. Hibernation in mammals. Quart. Rev. Biol., 6: 436–461.

LYMAN, C. P. 1948. The oxygen consumption and temperature regulation of hibernating hamsters. Jour. Exp. Zool., 109: 55–78.

SHAW, W. T. 1925. Observation on the hibernation of ground squirrels. Jour. Agri. Res., 31: 761–769.

SMITH, A. U., J. E. LOVELOCK, AND A. S. PARKES. 1954. Resuscitation of hamsters after supercooling or partial crystallization a body temperatures below 0°C. Nature, 173: 1136–1138

SUOMALAINEN, P. AND I. SUVANTO,. 1953. Studies on the physiology of the hibernating hedgehog. 1, The body temperature. Ann. Acad. Sci. Fenn., 4a, 20: 1–20.

SVIHLA, A. 1955. Resistance of hibernating ground squirrels to frostbite. Jour. Appl. Physiol., 7: 465–466.

VALENTIN, G. 1857. Moleschott's Untersuchungen.

WADE, OTIS. 1930. The behavior of certain spermophiles with special reference to aestivation and hibernation. Jour. Mamm., 11: 160–188.

Dept. of Zoology, Univ. of Washington, Seattle 5. Received April 15, 1957.

HIBERNATION IN *MESOCRICETUS AURATUS*

As a check on laboratory conditions designed primarily for a study of the hibernation of *Tamias striatus*, hamsters were exposed to cold. Although the hibernation of hamsters has been discussed by Lyman (Jour. Exp. Zool., 109: 55, 1948; Jour. Mamm., 35: 545, 1954), Chatfield and Lyman (Amer. Jour. Physiol., 163: 566, 1950), Kayser (Année Biol., 29: 109, 1953) and others, the present complementary observations merit brief mention.

Fourteen six-month-old *Mesocricetus auratus* Waterhouse, half of them males, were placed in a cold room at 3°±.5°C. Eight of these were of the white variety and were refrigerated on December 22, 1955. Three white hamsters of the same age were maintained in a constant-temperature warm room at about 20°C. as controls. Six of the golden variety were placed in the cold room on February 24, 1956; no controls were kept for these. The cold room was dark except for occasional brief periods required for adjustments and, except for the slight noise of a fan, there was relatively little disturbance.

The hamsters were placed in cages, each in a separate compartment, 14 × 8 × 5 in., containing a small nesting box and as much food (Purina laboratory chow) as could conveniently fit the rear area of the cage. The hamsters tended to pile the food in stacks around and in the nesting box. Water and food were abundantly available at all times.

The cold room was visited every one or two days. A little sawdust placed on the backs of torpid animals served as an indicator of movement during the periods between observations. Very slow respiratory movements, resulting in just a few movements per minute, were taken as indications of torpor. Sometimes this was verified by handling or by body temperatures. Possible states of lighter hibernation were not considered in this investigation. The experiment was interrupted on June 14, 1956.

Observations.—Two white hamsters died on February 25 and May 1, two golden hamsters on May 25 and April 11. Two golden hamsters became torpid during the experiment. One died while in torpor; another, its hibernation beginning on April 18, remained torpid, except for periodic awakenings, until the experiment was halted. During the last month of its hibernation it was found active 14 per cent of the times it was visited.

By May 5 all six surviving white hamsters had become torpid, and these remained in torpor until June 14. During this period they were found active 11 per cent of the times they were visited. As a rule, the hibernating animals woke at least every three or four days, most commonly every three days. One white hamster was apparently torpid for five days and, considering the periods of observation, might have been inactive for six.

When the experiment was terminated, surviving animals were placed in common cages for a short time. Within 15 minutes two white hamsters, awake on this day, cannibalized a torpid cagemate, biting it severely about the ears and face.

A few rectal temperatures of hibernators, taken by means of a thermocouple, indicated an average of 5.8°C. Weights at representative dates are given in Table 1. These include only those animals which survived the entire experimental period.

TABLE 1.—*Average weights and ranges, in grams*

DATE	6 WHITE HAMSTERS IN COLD ROOM	3 WHITE HAMSTERS IN WARM ROOM	4 GOLDEN HAMSTERS IN COLD ROOM
Dec. 22	86.2 (76–108)		
Jan. 19	87.7 (73–95)		
Feb. 24	88.0 (79–98)	98.3 (88–107)	126.5 (105–148)
March 22	83.0 (72–96)	——	115.8 (79–134)
Apr. 20	78.3 (72–90)	110.3 (96–119)	114.5 (98–132)
May 25	73.0 (69–80)	112.0 (91–122)	107.3 (88–125)
June 14	73.2 (66–80)	113.0 (93–126)	104.8 (92–120)

The duration of torpor noted and the weight losses of the golden hamsters upon cold exposure essentially confirm the summary of Lyman and Chatfield (Physiol. Rev., 35: 403, 1955). The white variety, maintaining their weight for several months, did not follow this weight pattern exactly. Even these, however, displayed a reaction to cold which differs considerably from that of *Citellus* and some other hibernators, which typically gain much weight and enter hibernation in an obese condition.—JOSEPH A. PANUSKA AND NELSON J. WADE, *Department of Biology, St. Louis Univ., St. Louis, Missouri.* *Received March 5, 1957.*

NORTHWARD EXTENSION OF THE KANGAROO RAT IN WASHINGTON

For many years kangaroo rats, *Dipodomys ordi*, have been blocked in their northward dispersal in Washington by the Columbia and Snake rivers. It was 100 years ago that Baird reported kangaroo rats in the Northwest. At the present time they are common over the sagebrush plains of eastern Oregon, occurring all along the south bank of the Columbia from The Dalles eastward for 140 miles to the Snake River (Bailey, N. Amer. Fauna 55: 235, 1936). In southeastern Washington they have been observed in western Walla Walla County only as far north as the Snake, and have been reported along the south bank of the river from its mouth for about 5 miles upstream. Kangaroo rats also occur in considerable numbers on Blalock Island in the Columbia River. This large island is several miles southwest of Paterson, Benton County, Washington. The northern limits of the range of *D. o. columbianus* have been given by Miller and Kellogg (U.S. Nat. Mus. Bull. 205: 403, 1955), Setzer (Univ. Kans. Publ., Mus., Nat. Hist., 1: 544, 1949) and Dalquest (*ibid.*, 2: 300, 1948).

Kangaroo rats now occur north of the Snake River in the triangle formed by the Snake and Columbia. I first observed signs of *Dipodomys* there in April of 1956, along the road leading east of Pasco to Levey. There were many burrows in the sandy soil along the right of way. The last of the dens were about 6 mi. ENE Pasco.

On April 28 specimens were obtained a few miles north of the Snake River east-northeast of Pasco. Twenty live traps were set on a small isolated sand dune about ¼ mile north of the highway; 6 *Dipodomys ordi* and 9 *Perognathus parvus* were captured. The surrounding country was rolling plains covered with a fairly dense growth of short grasses and sparsely scattered, low shrubs.

On May 6 I found tracks and four or five kangaroo rat dens on sandy ground a few miles north of Pasco (about ¼ mile southeast of the airport). This was about 5 miles northwest of the junction of the Snake and the Columbia.

A roadside check of the sagebrush plains and dry-farming wheat country north of Pasco was made on April 29. There were no signs of kangaroo rats on sandy areas north 36 miles to Connell, west of there 7 miles, and south through Mesa and Eltopia.

To check for kangaroo rats along the Washington shore of the Columbia River, I drove west from McNary Dam to Whitcomb on May 5 and 6, 1956. There was no evidence of *Dipodomys* on sandy areas along the road for a stretch of about 20 miles; nor were kangaroo rats caught in 40 traps set 1.5 mi. E Whitcomb in favorable habitat; only *Perognathus parvus* and *Peromyscus maniculatus* were taken. There were no signs of kangaroo rats on a dune hundreds of yards in diameter near Whitcomb.

There are ideal sand dunes on the north side of the Columbia near Umatilla. They extend for several miles in a narrow strip between the basalt bluffs and McNary Reservoir. There were no kangaroo rat dens or tracks on the sands in early spring. Ten traps set on these dunes at the north end of McNary Dam caught only *Peromyscus maniculatus* on February 28, 1956. A few days earlier I trapped several *Dipodomys ordi* on the south side of the river about 3 miles east of Umatilla.

Kangaroo rats were abundant on Blalock Island in the spring of 1956. Forty-eight live traps caught 11 *Dipodomys ordi*, 29 *Perognathus parvus*, and 4 *Peromyscus maniculatus* on March 31 and April 1 at the western tip of the island. The traps were set on sand dunes having scattered currant and sage bushes, and grassy flats between them.

It seems strange that there are no kangaroo rats on the Washington shore near Blalock Island. Though isolated from the Washington shore by part of the Columbia River, the main current of the river is on the south side of the island. Blalock Island is large (about 8 miles long and 1 mile wide), and has a great expanse of sand dunes, so the *Dipodomys* population may be fairly large.

One can speculate on how the kangaroo rats got onto the island. One possibility is that they were carried there by chance on farm trucks or some other conveyance. Cattle now graze on the island, and in the past some farming has been done there; one family lived there in 1956. A second possibility is that *Dipodomys* were cast up on the island by the river after ferrying across on floating debris. However, if this were the case, it would seem that there also should be kangaroo rats on the small sandy island just a few hundred feet downstream from Blalock. The habitat is ideal, but there are no *Dipodomys* there.

Spring floods on the Columbia and Snake are impressive. In April of 1956 I saw the Columbia when it rose to its peak flow. The water became extremely muddy and logs and debris of all sorts were swept downstream in great numbers. About a month later I saw a similar flood on the Snake River. It seemed likely that mice could have been carried away on floating objects. Some of them may land on islands or on the opposite shore. Along the banks of the Columbia there often is a fringe of willows and debris along the bank. They are half submerged during the highest floods. Mice could be cut off from shore in such places. Perhaps the caving in of banks or the isolation and flooding of sandy places beside the river might occasionally send kangaroo rats adrift.

Highway bridges also are possible routes for rodents to cross the Columbia and Snake rivers. There are three spans over the Columbia between The Dalles and Pasco, and one across the Snake near its mouth. All of them are about half a mile or more in length, but dispersing young adult animals might cross them. Possibly kangaroo rats got to the north side of the Snake by way of the bridge. The ground squirrel, *Citellus beecheyi*, also may have entered Washington over a bridge across the Columbia at White Salmon.

Small mammals may cross the rivers on the ice. Large pieces may break loose from one shore and be carried to the other; or a continuous sheet of ice may extend from bank to bank at times. I saw McNary Reservoir completely frozen over in the winter of 1955–56. Occasionally tugs came through and broke up the ice, but some of the time it would have been possible to cross over on the ice. Freezing of the river from bank to bank may become increasingly common with the construction of a series of dams along the Columbia. In the future the long and narrow reservoirs may often be covered with ice where in the past the river has been free.

Kangaroo rats undoubtedly will rapidly expand their range northward over the sagebrush plains of the Big Bend country of eastern Washington from their bridgehead near Pasco. Sand dunes along the Columbia River could serve as a dispersal route; the expanse of dunes at Moses Lake also appears to be an ideal habitat. Eventually *Dipodomys* may cross over the Columbia in southern Washington. There they will find excellent dunes up and down the length of the river. When this happens it will only be a matter of time until they occupy the Yakima Valley.

It will be interesting to compare the northward dispersal of *Dipodomys ordi* and the Californian ground squirrel, *Citellus beecheyi*, in Washington in the years to come. Both species have passed important barriers and are invading new territory. Around 1915 this ground squirrel crossed the Columbia River and entered Washington in the vicinity of White Salmon. By 1948 it had traveled east and north as far as Goldendale (Dalquest, *op. cit.*, 276). They have gone farther now. On August 9, 1950, I saw several of these ground squirrels along U.S. 97 about 7 mi. NNE Goldendale on the oak-pine south slope of the Simcoe Mountains. They were then within 7.9 miles of the summit of Satus Pass (altitude 3,149 feet). Seven years later (August 21, 1957) I drove over Satus Pass once more, and on this trip saw three of the ground squirrels 3.3 miles northeast of the pass. In these seven years the species had moved about 11 miles over the mountains.

In the 42 years since 1915 the California ground squirrel has spread at least 45 miles into the state of Washington; the rate of dispersal has been about 1.1 miles a year. It has passed over the southern rim of the Yakima Valley. Now it has a downhill trail ahead of it. At the present rate the species should reach the valley floor in about 20 years.—HAROLD E. BROADBOOKS, *Southern Illinois Univ., Alton, Ill.* *Received March 29, 1957.*

BREEDING OF *RATTUS ASSIMILIS* IN CAPTIVITY

Rattus assimilis of Australia, described by John Gould in 1858, has received very little scientific attention, although it is still fairly common in certain parts of that country. The present authors spent a year live-trapping the species in its native habitat in the Hawkesbury River area of New South Wales. At the end of this period, in August of 1955, 31 *Rattus assimilis* (14 ♀♀, 17 ♂♂) were trapped and flown to the United States. The animals arrived in apparently good condition, but eight died within the first two weeks. The remainder of the stock was divided into two colonies, of which one (5 ♀♀, 12 ♂♂) was kept at the University of California and the other (3 ♀♀, 3 ♂♂) was flown to Smith College. On October 21, 1955, one of the females (Smith College colony) gave birth to five young, four of which she raised successfully. This appears to be the first record of the breeding of *Rattus assimilis* in captivity. Young born subsequent to October of 1955 have now totaled over 250 in the two colonies.

The rats at the University of California have been maintained on Diet I (Nelson *et al.*, Jour. Nutrition, 56: 349–370, 1955) with a biweekly supplement of sunflower seed and greens or apple. Water is available at all times from standard animal watering bottles. The cages used measure 22 × 11½ × 10 in. and are covered by ¼-in. hardware cloth. The floor of the cage is wire of larger mesh, and a close-fitting, sliding drop pan tightly packed with sawdust prevents newborn young from falling through the openings. Each pair of rats is provided with nesting material and a small wooden nesting box. The male is removed from the cage when a litter is born. Following weaning of the young, the female is remated immediately.

The smallest of the cages used for mated pairs in the Smith College colony measures 8 × 12 × 18 in. Water, Purina laboratory chow, and nesting material are always available to the animals. Daily supplemental rations include carrots, apples, pears, grapes, oranges or greens. Wheat germ, powdered whole milk, oat meal, liver meal, sunflower seeds and hemp seeds are also given from time to time. The dry supplement given to particularly excitable animals is sometimes modified to contain 1 per cent, by weight, of either Miltown or Equanil. Cages so grooved that a sliding partition can be used to separate a male from his mate when young are born have been employed wherever possible to minimize human interference at a time when both of the adults are likely to be highly irritable.

The senior author is investigating certain aspects of the anatomy and behavior of *Rattus assimilis* while the junior author is studying its reproductive physiology.—B. Elizabeth Horner, *Dept. of Zoology, Smith College, Northampton, Mass.* and J. Mary Taylor, *Museum of Vertebrate Zoology, Univ. of California, Berkeley.* *Received March 11, 1957.*

A LITTER OF *RATTUS NAMAQUENSIS* BORN IN CAPTIVITY

The birth of *Rattus* (*Praomys*) *namaquensis* (A. Smith) in captivity has not as yet been reported. For this reason the following brief notes on the early development of a litter of this species may be of some value. The mother of the young here discussed was captured at Iscor Steelworks, Iscor, Pretoria, and was received on October 11, 1956. She was paired with a male received at the same time. On November 1 both animals were placed in a cage with an adjoining nestbox. On the next day, the female was found to have given birth to a litter of five. One of these had a head and body length of 37 mm., a tail of 20 mm. The others were of comparable size. Ventral color was pink, with sparse white hairs about 2 mm. long. The dorsal surface had a gray tinge and sparse black hairs, about 3–4 mm. long, were visible. Vibrissae were present, about 6 mm. long. Hands and feet were fleshy, as were the fingers and toes, which were equipped with claws less than 1 mm. long. The pinnae of three animals were open; in the remaining two they were folded down over the auditory opening.

Four of the young were attached to the mother's nipples and could not be dislodged, even by using a fair amount of force. The fifth was not attached and was removed for closer examination. This animal was found to have minute incisors, protruding for about 0.5 mm. from the gums of both upper and lower jaws. The firm grip of the other young on the nipples suggests that a similar condition prevailed in them.

On the basis of the small size of the urogenital papilla, and its proximity to the anus, as in newborn female *Rattus* (*Mastomys*) *natalensis*, the dislodged individual was sexed as a female. As no comparison with known *namaquensis* males or females was possible, this sexing must be regarded as provisional.

This young squirmed vigorously and squeaked loudly when handled, and crawled actively around when released. When returned to the nest the mother refused to accept it, attacking and inflicting severe bites on its head and neck. It was not yet dead when removed, and struggled feebly and soundlessly for some time, until etherized.

Subsequent development of the remaining young was followed by daily observations until the thirty-fourth day, at which time they appeared to be weaned and independent of further parental care. Observations were impeded by the fact that the young, until weaned, were virtually always attached to the mother's nipples, and usually partly hidden by her body. Furthermore, the mother was usually very nervous and excitable, and given to frenzied, aimless dashes around the cage and nestbox, with the young mice in tow, and seldom sat still long enough to enable me to examine the young thoroughly. This excitability appears to be common in captive *namaquensis*. As a result, weighing and measuring were impossible, and other observations were not as complete as might be desired.

It is assumed that the young were born on the day they were first discovered. This date is regarded as "zero" day, and subsequent days are called the first, second, etc. The observations below were made during the development of the young.

General.—All ear pinnae appeared to be open on the first day; on the tenth it appeared as if one or two young opened their eyes, but on the eleventh day the eyes were all closed when seen, and it was not until the twelfth day that the eyes were definitely open. On the twelfth day it was also possible to examine the young closely, and it appeared that sexes were readily distinguishable. One animal of the four was a female. The state of the sex organs suggested that at this stage sexes may have been already discernible for some time—in fact, as previously stated, it is possible that sexing may be possible at birth.

On the thirty-first day the female and one of the males were mated in a separate cage. The other two males were left with the parents until January 31, 1957, when they were nearly three months old.

Hair proliferation.—Development of the pelage was as follows:

1. Dorsal—On the second day the dorsal hair was quite dense, glossy black, and closely applied to the body. On the third day a buffy tinge was seen on the sides, in the zone of transition between the dark dorsal and pale ventral colors. This tinge was caused by the development of short buffy hairs in this zone. On the fourth day patches of buffy hairs were visible in front of the ears and laterally on the back of the head.

With the eruption of further buffy hairs during the ensuing days the buffy areas increased in size, spreading toward the rump and up the sides of the body. By the ninth day the buffy tinge had spread over the entire lateral surface, from the snout to the rump. By the thirteenth day it had spread over the whole body, with the exception of the dorsal surfaces of the head and back.

On the seventeenth day buffy hairs had appeared among the black hairs on the dorsal surface, so that the black color of this area was grizzled with buffy. After this, more buffy hairs rapidly appeared, until on the twentieth day the black color was practically obscured and few black hairs were visible. At this stage dorsal color was more or less uniformly dull buffy, less bright than that of adults. This color remained more or less unchanged for some time. On the thirty-fourth day, when regular observations were discontinued, the young were still much less brightly colored than the adults. However, color gradually became brighter until, around the end of January when the young were about three months old, they were indistinguishable in color from adults.

2. Ventral.—On the second day hair proliferation on the ventral surface had led to the appearance of a white tinge through which, however, the pink skin was still clearly visible. New hairs continued to appear, and from the seventh day onward ventral color was quite white, the skin being entirely covered by white hairs.

Size.—As it was impossible to weigh or measure the young during the early stages of their development, no accurate picture of size increase can be given. However, on the thirty-fourth day they were about one-third adult size. At 68 days average weight of the young was 66.5 gm. (62.7–69.6). At three months size was about as in small adults, but slightly smaller than in most adult animals seen. Average weight of seven adults was 79.4 gm. (64.0–93.7).

Activity.—There was little activity during the first weeks of life. One young was dislodged when first seen; when handled it was very active. On the first day another individual was dislodged, but soon reattached. With these two exceptions the young remained attached at all times when seen, until the eighteenth day. During this period there was very little activity, at most occasional stretching of the legs or shifting when touched. On the eighteenth day one young was again detached; on the nineteenth all were attached, but on the twentieth two were loose and very active, one in fact managing to escape from the cage.

From this day onward two or more young were always loose, and after the twenty-eighth day no young were seen attached. During this time, they became very active, running around the cage and nestbox and climbing on the cage wall, made of wire mesh. They also exhibited the nervousness and excitability of the adults, tending to run frantically and aimlessly at the slightest disturbance. This behavior has persisted to the present.

Weaning.—The young were first seen loose on the eighteenth day, and no young remained attached after the twenty-eighth. In view of this, weaning probably started on the former date, and all young were weaned on the latter.

Sexes.—Of the four surviving young, three are males. If the fifth individual was correctly sexed as a female, the sex ratio of the present litter was 60 per cent males at birth.

Gestation period.—The mother and her mate arrived and were paired on October 11. It is unlikely that mating occurred in captivity, for not only has this pair failed to produce subsequent litters, but so have several other pairs (including the two young of the present litter). This suggests that the gestation period is longer than 22 days.

Parental care.—The male showed little concern for the young, but neither did he show animosity. It should be kept in mind that there was little evidence that this male was the father of the litter in question.

The mother was never seen to give the young any care other than the protection of her presence. The reason for her killing one shortly after birth is not clear. Probably the chief cause was that it had been removed from the nest and handled. The fact that the pair had, only the previous day, been moved to a strange cage, and that they were unfamiliar with their new environment may have contributed.

Acknowledgments.—The author is indebted to R. B. Copley and S. G. P. Nienaber of Iscor Steelworks for providing the adult animals here discussed, and to J. T. Robinson and C. K. Brain, of the Division of Palaeontology, Transvaal Museum, for reading this paper, and for their constructive criticism of its contents.—J. MEESTER, *Transvaal Museum, Pretoria, South Africa. Received March 22, 1957.*

MELANISTIC *RATTUS NORVEGICUS* IN SOUTHWESTERN GEORGIA

Few studies of the prevalence of melanism in wild Norway rats have been published. The latest pertinent publication concerned the observations of Watson (Nature, 154: 334, 1944) in England. He noted that 21 of 1,266 *Rattus norvegicus* Erxl. trapped from several localities in the British Isles were melanistic and surmised that an incidence as high as 1.66 per cent could not be accounted for by mutation and recombination factors alone. Most studies in the United States have been concerned with the various color forms of the roof rat, *Rattus rattus* Linn. The melanistic Norway rat superficially resembles the black form of the roof rat, and it is of importance that this similarity be recognized in the application of rodent-control measures where these two species occur together as in southwestern Georgia. The occurrence of melanism in various species, which is also of interest to students of genetics and evolution, has been attributed to natural selection and heredity as well as to such factors as excessive heat and humidity, and chemical content of foods.

This study reports observations on melanistic, commensal Norway rats trapped from four counties in southwestern Georgia during the years 1954–1956. The study was made in connection with Newton Field Station investigations on the ecology of murine typhus fever.

Methods.—A total of 523 Norway rats were trapped in unbaited steel traps set in rat runs at 192 farms located in Baker, Grady, Mitchell and Thomas Counties, Georgia, during the period May, 1954 through November, 1956. Live rats were removed from the traps, placed in cloth bags, and transported to the laboratory. There they were anesthetized, bled and killed by cardiac puncture, weighed and measured. The sex was determined, and examinations were made for color and the presence of ectoparasites.

The blood serums from the rats were tested by complement fixation for the presence of murine typhus antibodies by the Communicable Disease Center's Virus and Rickettsial Diseases Laboratory at Montgomery, Alabama. Titers of 1:8 or better were considered positive evidence of typhus infection.

Results and discussion.—In Table 1, the prevalence of melanism in Norway rats is shown by county. One hundred (19.1 per cent) of the rats examined were black. Such a high prevalence of melanism appears to substantiate the findings of Keeler and King (Anat. Rec., 81: 48–49, 1941) who noted that this coat color is a simple, recessive, mendelizing unit-character. The black rats were fairly well distributed throughout Mitchell and Baker Counties, and approximately the northern two-thirds of Grady and Thomas Counties. They were taken from 61 of the 192 farms where rats were obtained. In most instances, they were found with other rats showing normal coloration.

The highest percentages of melanistic rats occurred in Grady and Thomas Counties where the most recent farm infestations by Norway rats have occurred (Ecke, Jour. Mamm., 35: 521–525, 1954). According to Ecke, this region represents the front of a southward invasion by the Norway rat advancing into territory previously occupied only by the roof rat. The farms in the southern third of these counties were predominantly occupied by roof rats at the time of this study. The higher percentage of melanistic Norway rats at the edge of the advancing front may be explained by the behavior and physiology which Keeler (Jour. Hered., 33: 371–384, 1942) found associated with laboratory-reared black Norway mutants. He noted that they were much more easily tamed and less pugnacious than the normally colored Norway rats, and that they were usually defeated in fights with their wild and savage typical Norway brothers. It appears reasonable to suspect that as the Norway rat populations reach stability within the infiltrated regions, the normal Norway rats tend to push the black mutants toward the less populated regions where there is less competition.

The normal sex ratio in Norway rats is believed to be near 1:1. If this is the true ratio, the results of trapping indicate that either female rats are more susceptible to the trapping technique used or that they survive better than males after being trapped. This is demonstrated for the typical color forms as well as for the melanistic ones (187 normal males, 236 normal females; 41 black males, 59 black females). The prevalence of melanism was about the same in both sexes (18 per cent of males black, 20 per cent of females black).

TABLE 1.—*Coloration of Rattus norvegicus in southwestern Georgia, May, 1954 to November, 1956*

COUNTY	NUMBER BROWN MALES	NUMBER BROWN FEMALES	NUMBER BLACK MALES	NUMBER BLACK FEMALES	TOTAL NUMBER RATS	PER CENT MELANISTIC
Baker	8	10	0	1	19	8.4
Mitchell	70	80	8	10	168	9.3
Grady	73	94	27	24	218	23.4
Thomas	36	52	6	24	118	25.4
Total	187	236	41	59	523	avg. 19.1

The prevalence of murine typhus antibodies in the normal and the black forms of *R. norvegicus* was approximately equal, 7.3 per cent and 7 per cent, respectively.

During the period covered by this report, only two black roof rats were seen among the total of 231 roof rats trapped in the southern third of Grady and Thomas Counties.—WILLIAM W. SMITH, *Communicable Disease Center, U.S. Public Health Service, Atlanta, and Emory Univ. Field Station, Newton, Georgia.* *Received March 14, 1957.*

ALBINISM IN THE WESTERN HARVEST MOUSE

Complete lack of pigment or pied coloration is common in some mammals; in others, such as the genus *Reithrodontomys*, these conditions are lacking or at least unreported. The western harvest mouse, *Reithrodontomys m. megalotis* (Baird), now may be added to the long and steadily growing list of wild and domestic animals in which albinism is known to occur.

Colonies of harvest mice and certain other native rodents were established at the Faunal Colony of Ecological Research to ascertain the practicability of mass-rearing these mammals in the laboratory for experimental purposes. Two albinistic individuals with pink eyes, one of each sex, were found in the fourth litter produced by a pair of wild-trapped harvest mice; three previous litters and three subsequent litters, totaling 17 young, born to this pair were all normal in color.

The albinos were reared to maturity and paired in May, 1955, but they did not produce litters until April, 1956, when one young was born. Twenty-five days later a second litter of two was born; 26 days later a third litter of three. All the young produced by these matings were albinos indicating that albinism in harvest mice is a recessive condition similar to that known for the common laboratory mouse, *Mus musculus*, and other laboratory animals.

This project was supported by U.S. Army Chemical Corps contract, No. DA-18-064-CML-2639, with the University of Utah.—HAROLD J. EGOSCUE, *Ecological Research, Univ. of Utah, Dugway.* *Received March 26, 1957.*

THE FULVOUS HARVEST MOUSE IN NEW MEXICO

Four specimens of the fulvous harvest mouse, *Reithrodontomys fulvescens* (Allen), were captured by us on three successive nights, January 27–30, 1957, 22 miles south and two miles east of Rodeo, Hidalgo County, New Mexico. The site of capture is located in the Peloncillo Mountains at the point where the Geronimo Trail (the road between Douglas, Arizona and the Animas valley, New Mexico) crosses the crest of the range at an altitude of approximately 5,900 feet. The animals were trapped at the entrances to burrows on an arid, southwest-facing hillside where annual grasses, yucca (*Yucca schottii*), century plant (*Agave* sp.) and beargrass (*Nolina microcarpa*) are common. Nearby north- and east-facing slopes support stands of alligator-bark juniper (*Juniperus pachyphloea*) and evergreen oaks (*Quercus* spp.). A few of these trees occur near the capture site.

The four specimens, all adult males (Nos. 2268, 2269, 2270 and 2271, University of New Mexico Collection of Vertebrates) have the following average and extreme external measurements in millimeters: total length, 160.8 (152.0–166.0); tail, 90.8 (85.0–95.0); hind foot, 19.5 (19.0–20.5); ear, 14.0 (13.0–15.0); weight in grams, 11.5 (9.9–12.7).

To our knowledge, this is the first record of the occurrence of *Reithrodontomys fulvescens* in New Mexico. The nearest reported record-station to the west is in the Huachuca Mountains, Cochise County, Arizona, a distance of approximately 75 miles from the Peloncillo Mountains. Animals from the Huachuca station have been referred to *R. f. fulvescens* (Allen) by Hoffmeister (Illinois Biol. Mon., 24(1): 114, 1954). The nearest record-station east of the Peloncillo Mountains is at Casas Grandes, Chihuahua, a distance of approximately 100 miles. Specimens from the latter station have been referred to *R. f. canus* Benson (Hooper, Misc. Publ. Mus. Zool., Univ. Mich., 77: 97–98, 1952). Our

specimens thus come from a locality intermediate in geographic position between the known ranges of these two subspecies. Hooper (*op. cit.*, 95) indicates that *R. f. canus* differs from *R. f. fulvescens* only in lesser warmth of the hues of the upperparts, and in grayish head and shoulders which are differentiated in color from the back and sides. Three of our specimens have grayish heads and shoulders which are more or less set off in color from the backs and sides of the animals. The fourth specimen does not show this characteristic distinctly. Our New Mexican specimens thus seem best referred to *Reithrodontomys fulvescens canus*.—James S. Findley and Barry E. Pullen, *Dept. of Biology, Univ. of New Mexico, Albuquerque. Received April 6, 1957.*

TERRITORIAL BEHAVIOR IN PIKAS

Pikas, *Ochotona princeps*, observed on successive week ends from September 4 to October 8, 1955 on a rock slide in the Sapphire Range in western Montana, exhibited well-marked territorial behavior. Brown, gray, and mixed color patterns induced by molting facilitated recognition of individual animals. The six pikas observed remained solitary within adjacent territories. They were often harvestng in early mornings, running to the upper or lower ends of the rock slide to cut stalks of grass or twigs from bushes. The pikas would then race back to their hay piles with the cut vegetation projecting from one side of their mouths. These mounds were really brush piles, with many woody twigs, but including items such as pine cones, clumps of moss and sprigs of Douglas fir. Pikas showed individual variation in the way they made their piles. Some animals hid their stores almost completely under rocks while others placed their mounds in the open.

The pikas could always be found in the same territories on the rock slide, remaining within boundaries in relation to adjacent territories. These areas may have enabled individuals to guard their food stores. When not active in harvesting, the pikas were often keeping watch over their territories, giving an occasional "caack" noise. A few observations suggested that this "caack" advertized ownership, rather than being a general note of alarm. For example, a longtail weasel, *Mustela frenata*, was on the rock slide on two successive mornings, September 4 and 5, where it was watched for a total of 20 minutes. The weasel ran in and out under logs and rocks, and occasionally raised its head and neck or even stood upright on its hind legs to peer about. It appeared to be hunting. Although a number of pikas remained in the open, not a single one made a "caack" while the weasel was in their vicinity. On October 8, Pika A invaded the territory of Pika B. The latter immediately ran toward the invader, which headed back the way it had come. Pika B continued to the actual rock where his neighbor had perched and called "caack" a number of times. Then he raced back to his brush piles.

Two observations suggested that pikas may mark their territories by scent. First, the bush piles were places where the animals left their droppings and on one occasion I actually saw a pika raise up on his hind legs to void on his stores. Another activity, observed not infrequently, was for pikas to stop and rub both cheeks against a rock as they ran about their territories. A possible interpretation of this action was that it spread the scent of the individual owner.

The territorial behavior of the pikas was similar, in general, to that previously observed for red squirrels, *Tamiasciurus hudsonicus* (Jour. Mamm., 35: 252-253, 1954), which was also based on an accumulation of autumn food stores, represented by pine cones. Pikas and squirrels both had an advertising call, remained within fairly definite boundaries, and chased out intruders of their own species. Pikas are unusual among lagomorphs in making calls from exposed places during the day. The above observations suggest that, in some situations, mammals may exhibit territorial behavior which parallels that found in birds in a number of its manifestations.—Lawrence Kilham, *7815 Aberdeen Rd., Bethesda, Maryland. Received March 5, 1957.*

CUVIER'S BEAKED WHALE FROM NORTHERN CALIFORNIA

Due to the scarcity of reports of beaked whales on the Pacific Coast of the United States it seems noteworthy to report the recent occurrence of Cuvier's beaked whale, *Ziphius cavirostris*, in Northern California.

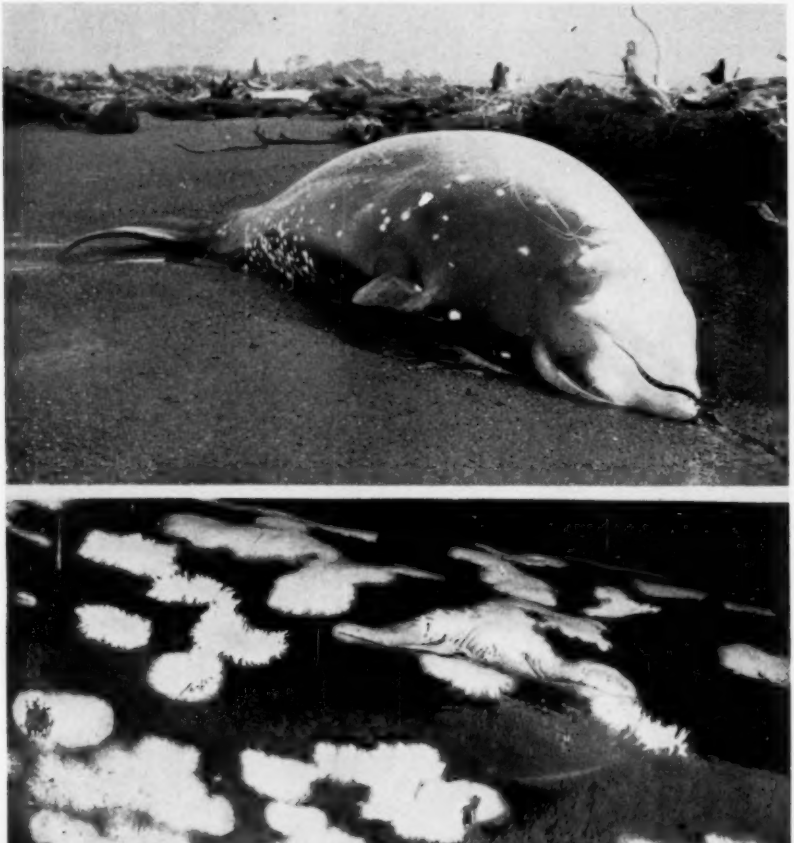


PLATE I

ABOVE: *Ziphius cavirostris* from northern California. Note the gular grooves and the two peg-like teeth showing in the lower lip. What appears to be a third tooth is a barnacle. BELOW: Close-up of the urogenital slit showing some of the numerous white scars.

During the night of March 1, 1957 a specimen of Cuvier's beaked whale washed ashore a few hundred yards north of the mouth of the Mad River, Humboldt County, California. The locality is about three miles north of Arcata, California. It was first observed by the author the following morning, and at that time it showed no evidence of external injury. It was in excellent condition. In fact, some of the flesh was used for human consumption.

The whale was 19 feet 7 inches long by a straight-line measurement made with a cloth tape. The ventral and lateral sides were predominantly black. The face was a cream color. This color extended dorsally to about half the length of the animal where it blended with the black of the flanks. The hide was smooth and firm and on it were numerous small oval scars (Plate I). These were located principally on the posterior ventral region but were not confined to this area. In addition the hide bore scratches some of which occurred in parallel pairs (Plate I). Only one barnacle was found on the whale. This was a stalked fleshy barnacle about 2 inches high which was located on the lower lip. The two peg-like teeth on the distal end of the mandible (Plate I) were the only teeth in evidence. By dissection it was ascertained to be a male. The stomach was devoid of food.

The skull, mandible, and a few vertebrae were saved and are now at Humboldt State College.

The author believes this constitutes the fourth report of this species on the west coast of the United States. The other occurrences are reviewed by Roest, Storm and Dumas (Jour. Mamm., 34: 251–252, 1953).

Another whale, a 45-foot sperm whale, was washed ashore at almost the identical spot as was this beaked whale, in May, 1955. As far as is known this sperm whale was not reported in the literature.—Warren J. Houck, *Humboldt State College, Arcata, Calif.* *Received April 6, 1957.*

ASPECTS OF BLOOD CHEMISTRY IN THE WHITE-TAILED DEER

Basic to an understanding of the biology of a species is adequate information on the chemical composition of the blood. A review of the readily available literature emphasizes a dearth of knowledge about the blood of cervids generally, although this group of mammals has significant economic importance. Wilber (1952) presented a brief item on the lipids in caribou blood. There are other scattered, and usually brief, reports of chemical constituents in the blood of cervids but apparently no extensive treatment of the subject has been made. Recently the opportunity presented itself of obtaining fresh blood samples from ten deer of the large herd inhabiting Aberdeen Proving Ground, Maryland. This paper reports the results of chemical analyses of these samples.

Materials and methods.—Eight male and two female deer were taken by shooting through the neck vertebrae. Blood (10 ml.) was immediately removed from the ventricle of the heart and transferred to a tube containing one drop of heparin. Total body weight and colonic temperature for each specimen were recorded. Values for sodium and potassium in the serum were obtained with the aid of a flame photometer. Corrections were made for sodium introduced by the heparin: one drop of heparin was put into a volume of distilled water equal to the volume of blood taken (10ml.); the mixture was treated as if it were blood. The final value for sodium in the water was subtracted from each "raw" serum sodium value to give the corrected value. Chloride was estimated titrimetrically (Sendroy, 1937); cholesterol (Zlatkis *et al.*, 1953) and inorganic phosphorus (Tausskey *et al.*, 1953) colorimetrically; calcium and magnesium titrimetrically (Grette, 1953).

Results and discussion.—The results are shown in Table 1. By inspection, there is no evident variation of body temperature or of blood composition with size or with age. In the domestic goat the average concentration of sodium in plasma is 150.5 mEq. per 1.; in cattle, 187.5 mEq. per 1. Blood chloride concentration in the latter is 105.5 mEq. per 1., in the former 105.3 mEq. per 1. It is evident that the plasma sodium and chloride values for *Odocoileus* are essentially the same as in domestic ruminants. Calcium and magnesium values fell within the normal range for mammals.

The following plasma potassium values have been reported in mEq. per 1.: *Cervus elaphus*, 6.04; *Cervus pseudaxis*, 5.52; *Rangifer tarandus*, 4.88. The domestic goat and cattle have values for plasma potassium of 5.01 and 6.55 mEq. per 1., respectively. Potassium in our plasma samples was routinely high with a mean of 10.43 mEq. per 1. Since all deer used by us had been shot, it is suggested that the hyperkaliemia is correlated with a state of shock in the beasts. Such increase in plasma potassium is a regular occurrence in human shock. The slightly elevated level of blood phosphorus (5.34 mEq. per 1. as compared with 3.25 and 4.41 for normal goats and cattle) is in accord with this view.

TABLE 1.—*Weights, sex, body temperature and certain blood constituents in ten white-tailed deer collected at Aberdeen Proving Ground, Maryland, on 13 November 1956*

NO.	WEIGHT, kg.	SEX	BODY TEMP., °C.	Na, mEq./1.	K, mEq./1.	Cl, mEq./1.	TOTAL CHOLEST., mg.%	INORG. PHOS., mg.%	TOTAL LIPID, mg.%
1	94.3	♂	37.8	174	7.9	104	29	10.5	500
2	33	♂	37.8	168	8.8	102	27	10.5	250
3	29.8	♀	38.0	168	10.8	102	30	9.3	450
4	40.7	♂	37.3	164	14.0	99	26	9.0	500
5	68	♂	37.8	171	11.4	102	26	9.3	300
6	65.5	♂	38.8	170	8.5	102	34	8.4	400
7	29.4	♀	37.7	188	11.0	99	32	10.2	350
8	29	♂	38.4	178	8.8	99	29	7.7	250
9	58	♂	38.4	174	12.4	99	33	9.0	450
10	49.8	♂	38.6	182	10.1	99	32	8.1	325
Mean	50	—	38.9	174	10.4	101	30	9.2	376

Total plasma cholesterol values for *Odocoileus* are much lower than those which Wilber (1952) found in the Alaskan caribou (68 mg. per 100 ml.). They are also lower than in goats or cattle. On the other hand, average total lipids in the white-tailed deer (Table 1) and in the caribou, 400 mg. per 100 ml. (Wilber, 1952), are practically identical. Goats have lower and cattle similar total plasma lipids. Low blood cholesterol values are seen widely in herbivores and rarely in carnivores. Nevertheless it has been denied that dietary habit is of great importance in determining serum cholesterol levels.

The body temperature of the Columbian black-tailed deer has been reported as 38.3 for adults and 38.8°C. for fawns. The ten deer in our sample were adults with a mean body temperature of 38.9°C. (Table 1). This value is close to that obtained for the caribou, 39.0, and for the reindeer, 38.8°C. The differences among published values may be related to species peculiarities but we suggest that variation of activity, immediately before temperature measurements were made, is of prime importance.

It is safe to conclude that the blood constituents of *Odocoileus virginianus*, as represented by our sample, show no remarkable peculiarities. Serum cholesterol is relatively low but in keeping with the trend among herbivores. Relatively high values for other constituents are explainable by the physiological state of the animals immediately before blood samples were taken.—CHARLES G. WILBER AND PAUL F. ROBINSON.

LITERATURE CITED

GRETTE, K. 1953. Micromethod for the determination of calcium and magnesium in serum. Scandinavian Jour. Clin. Lab. Investig., 5: 151–154.

SENDROY, J. 1937. Microdetermination of chloride in biological fluids with solid silver iodate. II. Titrimetric analysis. Jour. Biol. Chem., 120: 405.

TAUSSKEY, H., *et al.* 1953. A microcolorimetric method for the determination of inorganic phosphorus. Jour. Biol. Chem., 202: 675.
WILBER, C. G. 1952. Notes on the lipids in some wild mammals. Jour. Mamm., 33: 105.
ZLATKIS, A. *et al.* 1953. A new method for the direct determination of serum cholesterol. Jour. Lab. Clin. Med., 41: 486.

Physiology Division, Army Chemical Center, Maryland. Received March 19, 1957.

REVIEWS

Darlington, Philip J., Jr. ZOOGEOGRAPHY: THE GEOGRAPHICAL DISTRIBUTION OF ANIMALS. John Wiley & Sons, Inc., New York. Pp. xiii + 675, 80 figs. September 20, 1957. Price, $15.00.

Teachers of college courses in zoogeography, of whom there is an ever-increasing number, have long struggled with textbooks which were inadequate, obsolete, or biased toward one particular aspect of this inclusive field. They will welcome the appearance of this volume which honestly attempts to stress the over-all principles governing animal distribution, with passing consideration of special facets and a general appraisal of what, in the light of present evidence, seems to have occurred. This is a geographical, not an ecological or geological or historical, zoogeography. It is attractive in format, carefully organized and well indexed, practically free of typographical errors, and altogether a masterly job. The only bad feature is the inordinately high price, for this was not an expensive book to produce, as books go today.

The author, who is Curator of Insects at Harvard's Museum of Comparative Zoology, specializes in the taxonomy of beetles. Field studies have taken him several times to the West Indies, as well as to Colombia, Australia, New Guinea, the Philippines and Japan. Among the vertebrates, he knows birds the best, having watched and "collected them in a small way" since childhood. This detachment (in a curatorial sense) from vertebrates generally, together with a long interest in distributional problems and an association with such men as Thomas Barbour, M. L. Fernald and W. M. Wheeler, has been a happy combination making for a broad perspective and objective viewpoint. He has delved deeply into the literature and consulted widely with authorities on all groups concerned. He writes in a chatty yet authoritative style, cites appropriate statistics and examples, employs well-chosen diagrams and maps (the double orthographic rather than the familiar Mercator projection is used) and provides plentiful entries to published source material.

Vertebrates are regarded as the best-known and, geographically, the most significant animals. Thus, the book deals with land and fresh-water vertebrates of the world as a whole, though the faunas of South America and Australia are accorded special emphasis. The author's aim is to determine the main pattern of animal distribution, how and why it was formed, and what it tells us about ancient lands and climates. To do this, he first sets up seven sound rules of procedure or working principles as a guide to any proper zoogeographical undertaking. Five chapters deal with the vertebrate groups. For each the world-wide distribution is sketched, particular situations are outlined, and there follows a detailed list of the existing families with their present ranges, fossil records and other pertinent facts to serve as a base for deriving general principles.

Mammals are unique, in a zoogeographical sense, with their unequalled fossil record, despite its many gaps. Warmbloodedness has helped them to inhabit and traverse areas of cold; even more, their dominance—from superior endowments of one sort or another—has enabled them, as a group, to populate nearly all available parts of the world. Their dispersal has been limited most by salt-water barriers. Among flightless mammals, the rodents are by far the best water-crossers. "No limit can be set to the width of water an exceptional

rodent might cross. The ancestor of the native cricetids of the Galapagos apparently crossed more than 600 miles of ocean. It is possible . . . that the ancestor of the South American hystricomorph rodents came across the Atlantic from Africa, perhaps on a raft." (p. 322.)

There emerges a picture of the present distribution of vertebrates arrived at by dispersal of animals, through their own powers, over a world much as it is now with respect to land, climate and barriers. The Old World tropics is regarded as their center of origin. From here three main routes led southward: to temperate South Africa, from tropical Asia to Australia and New Zealand, and through temperate Eurasia and North America to tropical Central and South America. Contributing to this picture are five main subpatterns of distribution: (1) *limitation*, in area or numbers, northward in cold latitudes and outward from continents; (2) *zonation*, climatically or otherwise; (3) *geographical radiation*, best marked in fresh-water fishes; (4) *differentiation* of faunas on different continents; and (5) *concentration* in the largest, most favorable areas and subtraction marginally. Generalizations crop up left and right, e.g.:

> "North-temperate mammal faunas are essentially tropical faunas from which much has been subtracted. And the arctic mammal fauna is essentially a temperate fauna from which much more has been subtracted." (p. 341.)
>
> "Northernmost terrestrial vertebrates belong to primarily dominant groups rather than primarily cold-adapted groups." (p. 559.)
>
> "In each class of vertebrates more groups seem to have moved from the Old World to North and South America than the reverse." (p. 561.)
>
> "A zoogeographer is entitled to make his own estimate of a situation, and not to be too much bound by other people's theoretical impossibilities." (p. 582.)
>
> "Movements of animals into new places are usually not escapes but spreadings of dominant groups to obtain new advantages." (p. 627.)

As the best means of portraying how animals really are distributed with respect to space, climate, barriers, plant cover and other factors, the author again reaches the pattern of faunal regions first proposed by Sclater in 1857, on the basis of birds. These regions, "often misunderstood and undeservedly abused," represent an average pattern, not a common one; they are a real and useful concept. A. R. Wallace knew this well, and with his many contributions he stands forth as the giant among zoogeographers.

Scant justice can be done to the author's thesis in this review. He paints a clear picture (though not necessarily the only picture) and enumerates plausible principles. And he admits (p. 621) that these principles "could be subdivided and minor ones could be added indefinitely, but I do not want to do it. These principles—of the existence, nature, history, causes, and significance of the pattern; of complexity; of barriers that are more or less effective but not absolute; of competition and dominance and replacement; and of the fundamental importance of evolution with respect to area, climate, and barriers—are enough."

Controversial theories are mentioned and fairly evaluated. Continental drift is considered at some length, and the conclusion is reached (p. 606) that "the pattern of animal distribution as a whole fits the present pattern of land, climates, and barriers of the world, not the Wegenerian pattern." The proposed Tertiary connection between India and Africa is strongly discounted (p. 591). "Even the lemurs, for whom Lemuria was named, argue against it." Wolfson's idea of the origin of bird migration is considered (p. 244) as "sensational enough to be mentioned in a national news magazine and answered in *Science* . . . , but it hardly fits the facts." The arguments concerning Wallace's and Weber's Lines, demarcating the Oriental and Australian regions, are resurrected; the author feels (p. 472) that "perhaps recognition of a subtraction-transition area, Wallacea, is more likely to make the situation clear." Willis' age and area hypothesis is regarded (p. 549) as "a truism which is not new. That spreading equally in all directions is the main process . . . cannot be true. Receding has been important, too." Merriam's life zones are summarily

dismissed (p. 446) as "based on temperature . . . useful in some ways, but they have been overemphasized." The author has tried to be restrained in his criticism throughout the book; occasionally he cannot refrain from expressing his feelings, as when (p. 634) he writes: "There is no reasonable doubt that the Polynesians came from Asia, not from America, and the adventurers of the *Kon-Tiki* ought to accept this fact and be content with showing that a raft or two of Peruvian Indians may have reached Polynesia eventually and may have brought the sweet potato."

The book concludes with an entertaining and pithy account of the geographical history of man, treading lightly on anthropological and ethnological grounds. In summary, the author points out (p. 645) that "any large group of people can now, if they wish, draw ideas from the whole world and combine them with their own ideas to make better ones. The people who do this best, and who remember the old lesson that gains are more important than escapes (although escapes are important too), will probably hold or take power in the future. The people who cut themselves off from ideas, or who sacrifice gains to temporary security, will not hold power long. This, I think, is the plain lesson of the history of evolution and dispersal of animals and of man himself." One is reluctant to lay aside this informative and stimulating volume.—RICHARD H. MANVILLE.

Kempthorne, Oscar. AN INTRODUCTION TO GENETIC STATISTICS. John Wiley & Sons, Inc., N.Y. Pp. xvii + 545. 1957. Price, $12.75.

Kempthorne's INTRODUCTION TO GENETIC STATISTICS is an excellent treatment of those aspects of mathematical genetics most pertinent to the plant and animal breeder.

The book is divided into two nearly equal parts. The first of these is concerned with problems related to gene segregation at individual loci and includes such topics as the distribution and estimation of gene frequencies under random mating, inbreeding, and various conditions of mutation and selection.

The second part of the book is largely concerned with the inheritance of continuous characters, such as height and weight, and with partitioning the variance observed in such traits into genetic and environmental components.

The book contains only a brief account of evolutionary genetics and is for this reason unlikely to be of great value to mammalogists, who are more concerned with the evolutionary and ecological consequences of the mendelian mechanism than with applications to plant and animal husbandry. Although the book aims at being completely self-contained for readers with a knowledge of high school algebra, it is probable that the reader with no more mathematical background than this will find much of the book very difficult and some of it wholly inaccessible.—PHILIP J. CLARK.

RECENT LITERATURE

(Prepared by the Committee on Bibliography)

[Reprints of this section may be purchased from the Secretary-Treasurer]

ANSEL, W. F. H. Some mammals from Northern Rhodesia. Ann. & Mag. Nat. Hist., ser. 12, 10 (115): 529–550. July, 1957.

ARAMBOURG, C., AND P. BIBERSON. The fossil human remains from the Paleolithic site of Sidi Abderrahman (Morocco). Amer. Jour. Anthropol., n.s., 14 (3): 467–490, illus. September, 1956.

ASCHOFF, JÜRGEN AND JOHANNES MEYER-LOHMANN. Die 24-Stunden-Periodik von Nagern im natürlichen und künstlichen Belichtungswechsel. Zeitschr. Tierpsychol. 11 (3): 476–484. 1954. (With English summary.)

ASHTON, E. H. Age changes in the basicranial axis of the Anthropoidea. Proc. Zool. Soc. London, 129 (1): 61–74. September 9, 1957.

ASTRE, GASTON. Présence de l'elan à caylux dans la faune terminale des poches à phosphorites du Quercy. Mammalia, Paris, 21 (3): 238–240. September, 1957.

AUSTIN, C. R., AND M. W. H. BISHOP. Fertilization in mammals. Biol. Rev. Cambridge Phil. Soc., 32 (3):296–348. August, 1957.

BABAULT, GUY. Comportement des animaux dans les parcs du Kenya. Mammalia, Paris, 21 (3): 306–397. September, 1957.

BACKHOUSE, K. M., AND H. R. HEWER. A note on spring pupping in the grey seal (*Halichoerus grypus* Fab.). Proc. Zool. Soc. London, 128 (4): 593–594. July 24, 1957.

BAKER, RALPH C. Fur seals of the Pribilof Islands. Conservation in Action, U.S. Fish & Wildlife Service, 12: 1–24. 1957.

BERRYMAN, JACK H. Our growing need: a place to produce and harvest wildlife. Jour. Wildlife Management, 21 (3): 319–323. July, 1957.

BIGALKE, R. The bontebok [*Damaliscus pygargus* (Pall.)], with special reference to its history and preservation. Fauna & Flora, Transvaal, 6 (for 1955): 94–115, illus. 1957.

BIGALKE, R. Notes on the former and present occurrence of the sable antelope in the southern part of the Kruger National Park. Fauna & Flora, Transvaal, 6 (for 1955): 116–123. 1957.

BISHOP, M. W. H., AND C. R. AUSTIN. Mammalian spermatozoa. Endeavor, 16 (63): 137–150. July, 1957.

BÖKÖNYI, S. Trinkbecher aus Urhörnern in Ungarn. Säugetierk. Mitteil., Stuttgart, 4 (4): 145–150. October 1, 1956.

BROWN, K. G. The leopard seal at Heard Island, 1951–54. Interim Rept. Australian Nat. Antarctic Research Expeds., Melbourne, 16: 1–34 (mimeogr.), 4 pls. March, 1957.

BUBENIK, ANTONIN, AND RUDOLF PAVLANSKY. Von welchem Gewebe geht der eigentliche Reiz zur Gewiehentwicklung aus? II. Mitteilung: Operative Eingriffe auf den Rosenstöcken der Rehböcke, *Capreolus c. capreolus* (L., 1758). Säugetierk. Mitteil., Stuttgart, 4 (3): 97–103. July 1, 1956.

BURNETT, FRANCES L., AND CHARLES P. LYMAN. Biological investigations in the Selva Lacandona, Chiapas, Mexico: Mammals collected at Laguna Ocotal. Bull. Mus. Comp. Zool., 116 (4): 290–298. April, 1957.

BUTLER, H. The breeding cycle of the Senegal galago *Galago senegalensis senegalensis*. Proc. Zool. Soc. London, 129 (1): 147–149. September 9, 1957.

CHIA, LAN-PO, AND JEN-CHIEH CHAI. Quaternary mammalian fossils from Chihcheng, Hopei. Vertebrata Palasiatica, 1 (1): 47–56, 3 pls. March, 1957.

CHOW, MINCHEN M., AND HU CHANG-KONG. The occurrence of *Anchitherium aurelianense* at Fangshan, Nanking. Acta Pal. Sinica, 4 (4): 525–533, illus. 1956.

CHOW, MINCHEN M. Notes on some mammalian fossils from the late Cenozoic of Sinkiang. Vertebrata Palasiatica, 1 (1): 33–41. March, 1957.

CHOW, MINCHEN M. Note on a small collection of Pleistocene mammalian fossils from Tungnan, Szechuan. Vertebrata Palasiatica, (1): 57–58, 1 pl. March, 1957.

CHURCH, H. F. The times of emergence of the pipistrelle. Proc. Zool. Soc. London, 128 (4): 600–602. July 24, 1957.

CHURCHER, C. S. The fossil Hyracoidea of the Transvaal and Taungs deposits. Annals Transvaal Mus., 22 (4): 477–501. February 16, 1956.

CLARKE, ROBERT, AND S. G. BROWN. International co-operation in Antarctic whale marking from 1945 to 1957. Norsk Hvalfangst-Tidende (Norwegian Whaling Gazette), 46 (9): 513–517. September, 1957.

CONSTANT, PIERRE, AND BERNARD CANNONGE. Evaluation de la vitesse de vol des minioptères. Mammalia, Paris, 21 (3): 301–302. September, 1957.

COOK, ARTHUR H. Control of muskrat burrow damage in earthen dikes. New York Fish & Game Jour., 4 (2): 213–218. July, 1957.

CRANBROOK. Long tailed field mice (*Apodemus* sp.) from the Channel Islands. Proc. Zool. Soc. London, 128 (4): 597–600. July 24, 1957.

CROWCROFT, PETER. Field observation of the mole, *Talpa europaea*. Proc. Zool. Soc. London, 128 (4): 592. July 24, 1957. (Abstract.)

COURSEN, BLAIR. Naturalist at night. Turtox News, Chicago, 35 (8): 176–182. August, 1957. (Flashlight photos of animals.)

CSÍK, LAJOS. Grundstoffwechsel-Messungen an Haus- und Wildkaninchen. Annales Inst. Biol. (Tihany) Hungaricae Acad. Sci., 24: 3–10. 1957. (In Hungarian, with German summary.)

DALQUEST, WALTER W. First record of Bison alleni from a late Pleistocene deposit in Texas. Texas Jour. Sci., 9 (3): 346–354. September, 1957.

DALQUEST, WALTER W. Observations on the sharp-nosed bat, *Rhynchiscus nasio* (Maximilian). Texas Jour. Sci., 9 (2): 219–226. June, 1957.

DAUGHERTY, ANITA E. Whales and dolphins. A few notes about the giant of the sea and his clowning kin, the porpoise. Outdoor California, 18 (10): 3, 7, illus. 1957.

DAVIES, J. L. A hedgehog road mortality index. Proc. Zool. Soc. London, 128 (4): 606–608. July 24, 1957.

DAVIS, R. A. A survey of the mammal population of ricks in England and Wales, 1955–56. Proc. Zool. Soc. London, 128 (4): 604–606. July 24, 1957.

DEGERBØL, MAGNUS. The extinct reindeer of East-Greenland. *Rangifer tarandus eogroenlandicus*, subsp. nov. compared with reindeer from other Arctic regions. Acta Arctica, Copenhagen, 10: 1–66, map, pls. 1–11. 1957.

DELAP, PETER. Some notes on the social habits of the British deer. Proc. Zool. Soc. London, 128 (4): 608–612. July 24, 1957.

DELL, JOSEPH. An evaluation of the results of stocking imported cottontail rabbits in New York State. New York Fish & Game Jour., 4 (2): 121–149. July, 1957.

DELLA SERRA, OCTAVIO. O articulado dos dentes labiais nos símios da família *Cebidae* Swainson, 1835 (Primates–Mammalia). Papéis Avulsos Dept. Zool., Secretaria Agric., São Paulo, 12 (6): 165–188. May 16, 1955.

DELLA SERRA, OCTAVIO. Osteomielite após fratura bilateral do corpo da mandíbula do porco do mato (*Tayassu peccari* Fischer), com cura espontânea. Papéis Avulsos Dept. Zool., Secretaria Agric., São Paulo, 12 (15): 303–312. November 16, 1955.

DELOST, P. Recherches sur la biologie générale du campagnol des champs (*Microtus arvalis* Pallas). Bull. Soc. Zool. France, 45: 149–162. 1955.

DELOST, P. Anatomie et structure histologique de l'appareil genital du campagnol des champs (*Microtus arvalis* Pallas) adulte en active sexuelle. Bull. Soc. Zool. France, 45: 207–222. 1955.

DICK, JAMES, AND WILLIAM H. LAWRENCE. Protective seeding with tetramine-coated Douglas-fir seed. Forestry Research Notes, Weyerhaeuser Timber Co., Centralia, Washington, pp. 1–10 (mimeogr.). August, 1957. (Rodent control in reforestation.)

DIDIER, R., AND P. CANTUEL. Notes de tératologie comparée. Un cas de monstres monocéphaliens déradelphes chez le blaireau. Mammalia, Paris, 21 (3): 235–237. September, 1957.

Dorst, J., H. Heim de Balsac, and E. Morales-Agacino. Liste des noms français et espagnols des mammiféres d'Europe. Mammalia, Paris, 21 (3): 258–266. September, 1957.

Dorst, Jean. Note sur la dentition lactéale de *Tonatia amblyotis* (Chiroptères, Phyllostomidés). Mammalia, Paris, 21 (3): 302–304. September, 1957.

Dorst, Jean. Record de longévité d'un grand rhinolophe. Mammalia, Paris, 21 (3): 305. September, 1957.

Dorst, Jean. Un cas d'albinisme complet chez un rhinolophe euryale. Mammalia, Paris, 21 (3): 306. September, 1957.

Drexler, L., and H. Zapfe. Ein pathologisches skelett von *Smilodon* aus der argentinischen Pampaformation. Geologie, 5 (4–5): 288–307. 1957.

Edwards, R. Y., and I. McT. Cowan. Fur production of the boreal forest region of British Columbia. Jour. Wildlife Management, 21 (3): 257–267. July, 1957.

Eibl-Eibesfeldt, Irenäus. Zur Ethologie des Hamsters (*Cricetus cricetus* L.) Zeitschr. Tierpsychol. 10 (2): 204–254. 1953. (With English summary.)

Ellis, Derek V. Some observations on mammals in the area between Coppermine and Pond Inlet, N.W.T., during 1954 and 1955. Canadian Field-Nat., 71 (1): 1–6. 1957.

Emlen, John T., Jr., Ruth L. Hine, William A. Fuller, and Pablo Alfonso. Dropping boards for population studies of small mammals. Jour. Wildlife Management, 21 (3): 300–314. July, 1957.

Ennouchi, Emile. Nouvelles pièces d'hippopotames, de rhinocéros et d'éléphants marocains. Bull. Soc. Sci. Nat. & Phys. Maroc, 36: 307–317. 1956.

Fantl, P., and H. A. Ward. Comparison of blood clotting in marsupials and man. Australian Jour. Exper. Biol. & Med. Sci., 35 (3): 209–223. June, 1957.

Fellner, Albert. Beobachtungen an winterschlafenden Goldhamstern, *Mesocricetus auratus* (Waterhouse, 1837). Säugetierk. Mitteil., Stuttgart, 4 (3): 115–120. July 1, 1956.

Fellner, Albert. Der Sammeltrieb des syrischen Goldhamsters, *Mesocricetus auratus* (Waterhouse, 1839), im Laboratorium. Säugetierk. Mitteil., Stuttgart, 4 (4): 153–160. October 1, 1956.

Finlayson, H. H. Preliminary description of two new forms of *Bettongia* (Marsupialia). Ann. & Mag. Nat. Hist., ser. 12, 10 (115): 552–554. July, 1957. (New: *B. penicillata francisca, B. p. anhydra.*)

Fitz, Grancel North American head hunting. Oxford Univ. Press, New York, pp. xxvi +188, illus. 1957. (Big game trophy hunting.)

FitzSimons, V. An effective baboon trap. Fauna & Flora, Transvaal, 6 (for 1955): 78–83. 1957.

Fleay, Rosemary. Growing up with wombats. Animal Kingdom, New York Zool. Soc., 60 (4): 107–110, illus. August, 1957.

Flerow, Constantin C. A new coryphodont from Mongolia, and on evolution and distribution of Pantodonta. Vertebrata Palasiatica, 1 (2): 73–81. June, 1957. (New: *Procoryphodon, P. primaevus*).

Frank, Fritz. Beitrag zur Biologie insbesondere Jugendentwicklung der Schneemaus (*Chionomys nivalis* Mart.). Zeitschr. Tierpsychol., 11 (1): 1–9, 1954. (With English summary.)

Frank, Fritz, and Klaus Zimmermann. Über die Beziehungen zwischen Lebensalter und morphologischen Merkmalen bei der Feldmaus. Zool. Jahrb., Jena, 85 (3): 283–300. July, 1957.

Frechkop, Serge. A propos de nouvelles espèces de potamogalinés. Mammalia, Paris, 21 (3): 226–234. September, 1957.

FREYE, H.-A., G. GAFFREY, TH. HALTENORTH, D. MÜLLER-USING, AND H. POHLE. Die deutschen Namen der deutschen Säugetiere. Säugetierk. Mitteil., Stuttgart, 4 (4): 171–174. October 1, 1956.

FYFE, RICHARD W. "Taming the shrew." Blue Jay, Saskatchewan Nat. Hist. Soc., 15 (3): 120, illus. September, 1957. (Captive *Sorex*.)

GAISLER, J., AND V. HANÁK. Über einen Fund von *Myotis oxygnathus* Monticelli in der Tschechoslowakei. Věstniv Československé Zool. Společnosti (Acta Soc. Zool. Bohemoslovenicae), 20 (4): 364–365. 1956. (In Czech, with German and Russian summaries.)

GAISLER, J., V. HANÁK, AND M. KLÍMA. Netopýři Československa. Určovaci klíče, popisy a poznámky o výskytu. Acta Universitatis Carolinae, Prague, Biologica, pp. 1–65. 1957. (Chiroptera of Czechoslovakia.)

GAMA, MARIA MANUELA DA. Mamíferos de Portugal (chaves para a sua determinação). Mem. Estudos Mus. Zool. Univ. Coimbra, 246: 1–246. 1957.

GAZIN, C. LEWIS. Exploration for the remains of giant ground sloths in Panama. Annual Rept. Smithsonian Institution, Washington, 1956: 341–354, pls. 1–7. 1957.

GODFREY, GILLIAN K. Aggressive behaviour in the mole (*Talpa europaea* L.). Proc. Zool. Soc. London, 128 (4): 602–604. July 24, 1957.

GREENHALL, ARTHUR M. Bats of Trinidad. Jour. Trinidad Field Nat. Club, 1956: 16–18. 1956.

GREENHALL, ARTHUR M. Is the yapok or water opossum found in Trinidad? Jour. Trinidad Field Nat. Club, 1956: 27. 1956.

GRIFFO, JAMES V., JR. The status of the nutria in Florida. Quart. Jour. Florida Acad. Sci., 20 (3): 209–215. September, 1957.

GRZIMEK, BERNHARD. Über den Schlaf der Elefanten. Säugetierk. Mitteil., Stuttgart, 4 (3): 130. July 1, 1956.

GUILER, ERIC R. Longevity in the wild potoroo, Potorous tridactylus (Kerr). Australian Jour. Sci., 20 (1): 26. July, 1957.

GUNTHER, W. C. Some dietary effects on the estrous cycle of the female California pocket gopher, Thomomys bottae navus Merriam. Proc. Indiana Acad. Sci., 66: 331–336. 1957.

HANSEN, RICHARD M. Development of young varying lemmings (*Dicrostonyx*). Arctic, Jour. Arctic Inst. North Amer., 10 (2): 105–117. 1957.

HARDY, GEORGE A. Notes on the flora and fauna of the Blenkinsop Lake area on southern Vancouver Island, British Columbia. Rept. Provincial Mus. Nat. Hist. & Anthropol., Victoria, British Columbia, 1956: 25–66. 1957. (Mammals, pp. 58–59.)

HARRISON, DAVID L. Notes on African bats. I. Some systematic and anatomical notes on the African bats of the genus *Otomops* Thomas. Durban Mus. Nov., 5 (2): 17–26. September 1, 1957.

HAWKINS, A., AND J. OLSZEWSKI. Glia/nerve cell index for cortex of the whale. Science, 125 (3263): 76–77. July, 1957.

HEPTNER, V. G. The male genital tract and the systematic relations of Spermophilopsis leptodactylus Licht. (Mammalia, Sciuridae). Zool. Zhurn., Moscow, 36 (8): 1233–1238. 1957. (In Russian, English summary).

HEROLD, W. Über eine nicht gravid gewesene Ratte, die Mäuse säugt. Zeitschr. Tierpsychol., 11 (1): 138–140. 1954. (With English summary.)

HEROLD, WERNER. Zur Nahrung der Soriciden. Säugetierk. Mitteil., Stuttgart, 4 (3): 127. July 1, 1956.

HERTER, KONRAD, IMME-DAGMAR OHM-KETTNER, WOLFANG GEWALT, DIETRICH OHM, AND GÜNTER TEMBROCK. Über die Aufzucht und das Verhalten zweier Baummarder (*Martes martes* L.). Zeitschr. Tierpsychol., 11 (1): 113–137. 1954.

HEWER, H. R., AND K. M. BACKHOUSE. A red-headed grey seal (*Halichoerus grypus*). Proc. Zool. Soc. London, 128 (4): 592. July 24, 1957 (Abstract.)

HICKLING, GRACE. The grey seals of the Farne Islands. Trans. Nat. Hist. Soc. Northumberland, Durham and Newcastle upon Tyne, 12 (4): 93–133. September, 1957.

HILL, W. C. OSMAN. Primates: comparative anatomy and taxonomy. 3. Pithecoidea: Platyrrhini (Families *Hapalidae* and *Callimiconidae*). A monograph. University Press, Edinburgh, and Interscience Publishers, New York, pp. xix + 354, pls. 27. 1957.

HILL, W. C. OSMAN, ANNIE PORTER, R. T. BLOOM, J. SEAGO, AND MARGARET D. SOUTHWICK. Field and laboratory studies on the naked mole rat, *Heterocephalus glaber*. Proc. Zool. Soc. London, 128 (4): 455–514, pls. 1–8. July 24, 1957.

HRUBESCH, KARL. Zahnstudien an tertiären Rodentia als Beitrag zu deren Stammesgeschichte. Über die Evolution der Melissiodontidae, eine Revision der Gattung *Melissiodon*. Bayer. Akad. Wiss., Mathem-Nat. Kl., 83: 1–101, illus. 1957. (New: *Melissiodon schalki, M. schroderi*).

HU, CHANG-KANG. An antler fragment of *Stephanocemas* and some teeth of *Aceratherium* from Linchü, Shantung. Vertebrata Palasiatica, 1 (2): 163–166, 1 pl. (Summary in English). June, 1957.

HUEY, LAURENCE M. A new race of wood rat (Neotoma) from the Gulf side of central Baja California, Mexico. Trans. San Diego Soc. Nat. Hist., 12 (15): 287–288. September 25, 1957. (New: *N. lepida aridicola.*)

IABLOKOV, A. V. On the interesting function of white coloration. Nature, Moscow, no. 6: 92–94. June, 1956. (In Russian.)

IVANOV, O. A. On the mobility and diurnal activity rhythm of the marmots (Citellus pygmaeus Pall.) in western Kazakhstan in different periods of their activity. Zool. Zhurnal, Moscow, 36 (6): 922–932. 1957. (In Russian with English summary.)

JAMES, GIDEON T. An edentate from the Pleistocene of Texas. Jour. Paleontol., 31 (4): 796–808. July, 1957.

JENKINS, DAVID. A note on the abundance of harvest mice (*Micromys minutus*) in North Hampshire in 1955. Proc. Zool. Soc. London, 128 (4): 604. July 24, 1957.

JONSGÅRD, ÅGE, AND PEDER HØIDAL. Strandings of Sowerby's whale (*Mesoplodon bidens*) on the West Coast of Norway. Norsk Hvalfangst-Tidende (Norwegian Whaling Gazette), 46 (9): 507–512, illus. September, 1957.

KANÔ, K., A. AWA, AND A. SATO. A preliminary note on the short-tail in Long-Evans rats. Misc. Repts. Yamashina's Inst. Ornithol. & Zool., 10: 22–23 (408–409). June, 1957. (In Japanese, with English summary.)

KETTLITZ, W. K. A preliminary report on the distribution of certain species of game in the Transvaal (1954). Fauna & Flora, Transvaal, 6 (for 1955): 124–151. 1957.

KING, JUDITH E. On a pup of the crabeater seal *Lobodon carcinophagus*. Ann. & Mag. Nat. Hist., ser. 12, 10 (116): 619–624. August, 1957.

KIRKPATRICK, CHARLES M., AND EDWARD M. BARNETT. Age criteria in male gray squirrels. Jour. Wildlife Management, 21 (3): 341–347, illus. July, 1957.

KLUMOV, S. K. On the cycle of increase of the black "belobochki" dolphin (*Delphinus delphis ponticus* Barab.). Trudy Inst. Okeanol., Akad. Nauk SSSR, Moscow, 7: 206–219. 1954.

KLUMOV, S. K. On the locating of whale herds. Trudy Inst. Okeanol., Akad. Nauk SSSR, Moscow, 18: 7–27. 1955.

KLUMOV, S. K. Some results of the expedition to the Bering Sea and to the Kurile Islands. Vestnik Akad. Nauk SSSR, 5: 32–37, map. 1956.

KRETZOI, M. Dolomys and Ondatra. Acta Geol., 3(4): 347–355. 1955.

KRETZOI, M. Promimomys cor n.g., n.sp., ein altertümlicher Arvicolide aus dem ungarischen Unterpleistozän. Acta Geol., 3 (1–3): 89–94, illus. 1955.

KRETZOI, M. Die altpleistozänen Wirbeltierfaunen des Villányer Gebirges. Geol. Hungarica, ser. paleo., 27: 1–264. 1956.

KROTT, PETER. Das Wiederfinden eines auf einem Transport entsprungenen Vielfrasses. Zeitschr. Tierpsychol., 10 (2): 254–268. 1953. (With English summary.)

KROTT, PETER. Über einen Versuch, zwei Elche als Zugtiere zu benützen. Zeitschr. Tierpsychol., 11 (2): 304–318. 1954. (With English summary.)

KRUMBIEGEL, INGO. Der Begriff der Eremaporie. Säugetierk. Mitteil., Stuttgart, 4 (3): 126–127. July 1, 1956.

KRYLTSORA, A. I. Weight changes of Lagurus lagurus Pall. with their sex and age. Zool. Zhurn., Moscow, 36 (8): 1239–1250. 1957. (In Russian, with English summary.)

KÜHN, ERICH. Simultanvergleich gesehener Mengen beim Rhesusaffen. Zeitschr. Tierpsychol., 10 (2): 268–296. 1953. (With English summary.)

KUMERLOEVE, H. Kaninchen, *Oryctolagus cuniculus* (Linné, 1758) und Hasen, *Lepus europaeus* Pallas, 1778, als Pilzfresser. Säugetierk. Mitteil., Stuttgart, 4 (3): 125–126. July 1, 1956.

KURTÉN, BJÖRN. A note on the systematic and evolutionary relationships of *Felis teilhardi* Pei. Vertebrata Palasiatica, 1 (2): 123–128. June, 1957.

LANZA, BENEDETTO. Su alcuni chirotteri della Penisola Balcanica. Presenza di *"Eptesicus nilssoni nilssoni"* (Keyserling e Blasius, 1839) in Jugoslavia. Monitore Zool. Italianio, 65 (1–2): 3–6. September, 1957.

LAVOCAT, R. La faune de rongeurs des Grottes a Australopithèques. Pal. Africana, 4: 69–75, illus. 1956. (New: *Mystromys darti.*)

LAWRENCE, WILLIAM H. Porcupine control: a problem analysis. Forestry Research Notes, Weyerhaeuser Timber Co., Centralia, Washington, pp. 1–43 (mimeogr.). July, 1957.

LEVER, R. A. Two records of foxes eating larval hover flies and dor beetles. Proc. Zool. Soc. London, 128 (4): 596–597. July 24, 1957.

LEYHAUSEN, PAUL. Über die unterschiedliche Entwicklung einiger Verhaltensweisen bei den Feliden. Säugetierk. Mitteil., Stuttgart, 4 (3): 123–125. July 1, 1956.

MAMMAL SOCIETY OF THE BRITISH ISLES. Report of ringing and returns of grey seals: No. 1. September 1954–August 1956. Proc. Zool. Soc. London, 128 (4): 594–596. July 24, 1957.

MANI, M. S. The abominable snow-man. Turtox News, Chicago, 35 (8): 172–173. August, 1957. (Track of Himalayan bear.)

MARSHALL, J. T., JR. Atolls visited during the first year of the Pacific Islands rat ecology project. Atoll Research Bull., Pacific Science Board, no. 56, pp. 1–11. September 15, 1957.

MEESTER, J. A mammal survey of the S. A. Lombard Nature Reserve (1954). Fauna & Flora, Transvaal, 6 (for 1955): 44–57. 1957.

MEYER, KARL F. The natural history of plague and psittacosis. Public Health Repts., U.S. Public Health Service, Washington, 72 (8): 705–717. August, 1957.

MOHR, CARL O., AND WILLIAM W. SMITH. Eradication of murine typhus fever in a rural area. Preliminary report. Bull. World Health Organization, 16: 255–266. 1957.

MOHR, ERNA. Sirenen oder Seekühe. Neue Brehm-Bucherei, A. Ziemsen Verlag, Wittenberg Lutherstadt, pp. 61, illus. 1957.

MOHR, H., AND M. MOTTL. Funde von Steingeraten aus altpleistozänen Schottern im Raume von Wien. Eiszeitalter & Gegenmart, 7: 193–218. August, 1956.

MONDOLFI, EDGARDO, AND JOSÉ LUIS MENDEZ A. Un nuevo conejo de monte de Venezuela. Mem. Soc. Ciencias Nat. La Salle, Caracas, 17 (46): 17–25. 1957. (New: *Sylvilagus brasiliensis caracasensis.*)

Moore, Joseph Curtis. The natural history of the fox squirrel, *Sciurus niger shermani*. Bull. Amer. Mus. Nat. Hist., 113 (1): 1–71, pls. 1–3. August 26, 1957.

Moser, Clifford A., and Lyndle Dunn. Colorado's "split-hoofed" big game animals. Colorado Outdoors Mag., 6 (5): 16–17 and front cover. September, 1957.

Müller, G. Geschlechtsunterschiede am Becken der Bisamratte, *Ondatra zibethica* (Linné, 1766). Säugetierk. Mitteil., Stuttgart, 4 (4): 150–153. October 1, 1956.

Nagy, Eugen. Der Ausgerottete ungarische Rohrwolf (*Canis lupus*) war kein Schakal (*Canis aureus*). Säugetierk. Mitteil., Stuttgart, 4 (4): 165–167. October 1, 1956.

Nero, Robert W. Short-tailed shrew records. Blue Jay, Saskatchewan Nat. Hist. Soc., 15 (3): 121. September, 1957. (*Blarina* in Saskatchewan.)

Nero, Robert W. New silver-haired bat records. Blue Jay, Saskatchewan Nat. Hist. Soc., 15 (3): 121. September, 1957.

Ogilvie, A. G. The initiation of a study of mortality and morbidity in the Farne Islands grey seals nurseries. Trans. Nat. Hist. Soc. Northumberland, Durham and Newcastle upon Tyne, 12 (4): 134–136. September, 1957.

Omura, Hideo. Report on two right whales caught off Japan for scientific purposes under Article VIII of the International Convention for the Regulation of Whaling. Norsk Hvalfangst-Tidende (Norwegian Whaling Gazette), 46 (7): 374–390, illus. July, 1957.

Parker, Richard L., James W. Kelly, E. L. Cheatum, and Donald J. Dean. Fox population densities in relation to rabies. New York Fish & Game Jour., 4 (2): 219–228. July, 1957.

Paulian, Patrice. Note sur les phoques des Iles Amsterdam et Saint-Paul. Mammalia, Paris, 21 (3): 210–225, pls. 7–8. September, 1957.

Pei, Wen-chung. The zoogeographical divisions of Quaternary mammalian faunas in China. Vertebrata Palasiatica, 1 (1): 9–24. March, 1957.

Pei, Wen-chung, and Chung-lang Chiu. On a collection of mammalian fossils from Liuhsia, Hongchow, Chekiang, China. Vertebrata Palasiatica, 1 (1): 42–46. March, 1957.

Pei, Wen-chung. Discovery of *Gigantopithecus* mandibles and other material in Liu-Cheng District of Central Kwangsi in South China. Vertebrata Palasiatica, 1 (2): 65–72, 3 pls., June, 1957.

Petter, Francis. Liste commentée des espèces de gerbillidés de Palestine. Mammalia, Paris, 21 (3): 241–257. September, 1957.

Petter, Francis. La reproduction du fennec. Mammalia, Paris, 21 (3): 307–309. September, 1957.

Pijl, L. van der. Classification of the leguminous fruits according to their ecological and morphological properties. Proc. Kon. Nederlandse Akad. Wetensch., ser. C, 59 (3): 301–313. 1956. (Dissemination by bats and other mammals, pp. 304–305.)

Pijl, L. van der. Remarks on pollination by bats in the genera Freycinetia, Dubanga and Haplophragma, and on chiropterophily in general. Acta Botanica Neerlandica, 5 (2): 135–144, pls. 1–2. August, 1956.

Pijl, L. van der. The dispersal of plants by bats (chiropterochory). Acta Botanica Neerlandica, 6: 291–315. 1957.

Pilters, Hilde. Untersuchungen über angeborene Verhaltensweisen bei Tylopoden, unter besonderer Berücksichtigung der neuweltlichen Formen. Zeitschr. Tierpsychol., 11 (2): 213–303. 1954. (With English summary.)

Pirlot, P. Notes de route sur l'écologie des mammifères entre le Bas-Congo et le Kivu. Bull. Agric. Congo Belge, Brussels, 48 (2): 393–408. 1957.

Pirlot, P. L. Rongeurs nuisibles aux cultures des environs du lac Kivu (Congo belge). Bull. Agric. Congo Belge, 48 (3): 703–730, illus. 1957.

PIRLOT, P. L. Associations de rongeurs dans les régions hautes de l'est du Congo belge et du Ruanda-Urundi. Rev. Zool. Bot. Africain, 55 (3–4): 224–236. July 20, 1957.

PORTER, ANNIE. Morphology and affinities of entozoa and endophyta of the naked mole rat *Heterocephalus glaber*. Proc. Zool. Soc. London, 128 (4): 515–527, pls. 1–2. July 24, 1957.

PRECHT, H., AND E. LINDENLAUB. Über das Heimfinderermögen von Säugetieren. I. Versuche an Kätzen. Zeitschr. Tierpsychol., 11 (3): 485–494. 1954. (With English summary.)

PRESNALL, CLIFFORD C. Control de los animales silvestres vectores de rabia a lo largo de la frontera Mexicano-Estadounidense. Bol. Oficina Sanitaria Panamericana, 43 (2): 159–161. August, 1957. (With English summary.)

QUAY, W. B., AND J. F. QUAY. The requirements and biology of the collared lemming, *Dicrostonyx torquatus* Pallas, 1778, in captivity. Säugetierk. Mitteil., Stuttgart, 4 (4): 174–180. October 1, 1956.

RASS, T. S., A. G. KAGANOVSKII, AND S. K. KLUMOV. The geographical distribution of fish and other economic animals of the Okhotsk and Bering Seas. Trudy Inst. Okeanologii, Akad. Nauk SSSR, Moscow, 14: 1–120, illus. 1955. (Part 3, cetaceans; part 4, pinnipeds; in Russian.)

RENSCH, B., AND R. ALTEVOGT. Zähmung und Dressunleistungen indischer Arbeitselefanten. Zeitschr. Tierpsychol., 11 (3): 497–519. 1954. (With English summary.)

RIEDEL, ALFREDO. Contributo alla conoscenza degli animali domestici delle torbiere del Garda. Mem. Mus. Civico Storia Nat. Verona, 5: 61–88, pls. 1–7. December 15, 1955.

ROTH, HELLI. Beobachtungen am Gundi, *Ctenodactylus gundi* (Rothmann, 1776). Säugetierk. Mitteil., Stuttgart, 4 (3): 120–123. July 1, 1956.

ROTHSCHILD, MIRIAM, AND CHARLES LANE. Note on change of pelage in the stoat (*Mustela erminea* L.). Proc. Zool. Soc. London, 128 (4): 602. July 24, 1957.

SAINT GIRONS, MARIE-CHARLOTTE. Les factures écologiques du cycle journalier d'activité chez quelques petits mammifères français. Mammalia, Paris, 21 (3): 197–209. September, 1957.

SCHNEIDER, ROLF. Metrische Untersuchungen am Grosshirn der Chiroptera. Anat. Anzeiger, Jena, 104 (6–10): 142–149. July, 1957.

SCHULTZ, C. BERTRAND, AND LLOYD G. TANNER. Medial Pleistocene fossil vertebrate localities in Nebraska. Bull. Univ. Nebraska State Mus., 4 (4): 59–81. September, 1957.

SCHULTZ, VINCENT, AND ROBERT J. MUNCY. An analysis of variance applicable to transect population data. Jour. Wildlife Management, 21 (3): 274–278. July, 1957. (White-tailed deer populations.)

SCHULTZ, VINCENT, AND MITCHELL A. BYRD. An analysis of covariance of cottontail rabbit population data. Jour. Wildlife Management, 21 (3): 315–319. July, 1957.

SCOTT, J. P. Animal and human children. Children, 4 (5): 163–168. 1957.

SETZER, HENRY W. The hedgehogs and shrews (Insectivora) of Egypt. Jour. Egyptian Publ. Health Assoc., Cairo, 32 (1): 1–17. March 28, 1957. (New: *Hemiechinus auritus metwallyi, Paraechinus deserti wassifi.*)

SHERMAN, H. B. General biotic relations of the Florida mammal fauna. Quarterly Jour. Florida Acad. Sci., 20 (3): 149–173. 1957.

SIMONETTA, ALBERTO. Condrocranio e dermascheletro di "Chrysochloris asiatica" (Linnaeus). Monitore Zool. Italiano, 65 (1–2): 28–47. September, 1957.

SMIRNOV, V. S. The squirrel Scuirus vulgaris exalbidus Pall. in the forest-steppe of Transural. Zool. Zhurnal, Moscow, 36 (6): 933–937. 1957. (In Russian, with English summary.)

STEIN, GEORG. Zur Ökologie norddeutscher Gartenspitzmäuse, *Crocidura suaveolens mimula*, Miller, 1917. Säugetierk. Mitteil., Stuttgart, 4 (3): 130. July 1, 1956.

STEINIGER, F. Über das Anlocken von Ratten durch Pfeiftöne. Zeitschr. Tierpsychol., 11 (1): 141–143. 1954. (With English summary.)

STEINHOFF, HAROLD. The buck with 2 points. Colorado Outdoors Mag., 6 (5): 28–29. September, 1957. (18-year record of antler growth in mule deer.)

STIRTON, R. A. A new koala from the Pliocene Palankarinna fauna of South Australia. Records South Australian Mus., Adelaide, 13 (1): 71–82. April 30, 1957. (New: *Perikoala, P. palankarinnica.*)

STOHL, GÁBOR. Über die Stellung der Lagomorpha im System der Säugetiere. Annales Inst. Biol. (Tihany) Hungaricae Acad. Sci., 24: 51–57. 1957. (In Hungarian, with German summary.)

STOHL, GÁBOR. Über die Kreatinin-Ausscheidung bei einigen Kaninchenrassen. Annales Inst. Biol. (Tihany) Hungaricae Acad. Sci., 24: 59–65. 1957. (In German.)

STRAUSS, FRITZ. Die Placenta des Feldhasen. Acta Anatomica, Basel, 30: 815–826. 1957.

STRAUSS, FRITZ. Theodor Langhans und die Placentologie. Mitteil. Naturf. Gesell. Bern, neue Folge, 14: 33–48. 1957.

STRAUSS, FRITZ. Neue Geschichtspunkte über Bau und Leistung der Placenta. Mitteil. Naturf. Gesell. Bern, neue Folge, 15 (Sitzungsber.): vii–viii. 1957.

STRAUSS, FRITZ. Die Implantationsvorbereitungen im Hamster-Uterus. Verhandl. Anatomischen Gesellschaft 53. Versammlung, Stockholm, 1956, pp. 92–98. 1957.

TACHEZY, RUDOLF. Über den Einfluss der Sexualhormone auf das Gewiehwachstum der Cerviden. Säugetierk. Mitteil., Stuttgart, 4 (3): 103–112. July 1, 1956.

TAKAI, FUYUJI. An addition to the mammalian fauna of the Japanese Miocene. Jour. Faculty Sci. Univ. Tokyo, Sec. 2, 9 (2): 331–335. October 31, 1954. (New: *Palaeocherus japonicus.*)

TAMSITT, J. R. *Peromyscus* from the late Pleistocene of Texas. Texas Jour. Sci., 9 (3): 355–363. September, 1957.

TAYLOR, H. W. Y., J. B. KING, AND ROBERT M. STECHER. Osteoarthritis of the hip in gorillas. Report of two cases. Clinical Orthopaedics, 6: 149–157. 1955.

TENIUS, KARL. Wieder zwei Wölfe in Niedersachsen erlegt! Säugetierk. Mitteil., Stuttgart, 4 (3): 127–128. July 1, 1956.

TENIUS, KARL. Zur Standorttreue des Mausohrs, *Myotis m. myotis* (Borkhausen, 1797) im Winterquartier. Säugetierk. Mitteil., Stuttgart, 4 (3): 128–129. July 1, 1956.

TOEPFER, VOLKER. Die Mammutfunde von Pfännerhall im Geiseltal. Veröffent. Landesmus. Vorgesch. Halle, 16: 1–58, illus. 1957.

TOMILIN, A. G. Mammals of USSR and adjacent regions. Vol. IX. Cetaceans. Akad. Nauk SSSR, Moscow, pp. 756, pls. 11. 1957. (Continuation of "Mammals of Eastern Europe and Northern Asia" by S. I. Ognev. In Russian.)

TRAINER, DANIEL O., JR. What about rabies? Wisconsin Conservation Bull., 22 (9): 15–18, map. September, 1957.

TROUGHTON, ELLIS. The kangaroo family. Australian Mus. Mag., 12 (7): 230–237. September 15, 1957.

TURCEK, F. J. Über den Mufflon, *Ovis musimon* Schreber, 1782, in der Slowakei (CSR). Säugetierk. Mitteil., Stuttgart, 4 (4): 167–171. October 1, 1956.

TWIST, T. F., AND D. M. TWIST. Record of a beaked whale from Balandra. Jour. Trinidad Field Nat. Club, 1956: 26–27. 1956.

UHLIG, HANS G. Gray squirrel populations in extensive forested areas of West Virginia. Jour. Wildlife Management, 21 (3): 335–341. July, 1957.

ULBRICH, WOLFGANG. Zur Frage des Sichselbstbespuckens bei Säugetieren. Zeitschr. Tierpsychol., 11 (1): 150. 1954. (With English summary.)

URICH, F. W., AND LUDOLF WEHEKIND. Notes on some Trinidad bats. Jour. Trinidad Field Nat. Club, 1956: 18–21. 1956.

WASHBURN, S. L. Ischial callosities vs. sleeping adaptations. Amer. Jour. Phys. Anthropol., n.s., 15 (2): 269–276. June, 1957. (Baboons.)

WAUGH, F. L. Hunting the mule deer. Colorado Outdoors Mag., 6 (5): 6–11. September, 1957.

WEBER, BRUNO. Hamster klettern auf Sonnenblumen. Säugetierk. Mitteil., Stuttgart, 4 (3): 131. July 1, 1956.

WICKINGEN, HEINRICH. Über die Geschlechtsbestimmung bei Tüpfelhyänen, *Crocotta crocuta* (Erxleben 1777). Säugetierk. Mitteil., Stuttgart, 4 (3): 129–130. July 1, 1956.

WIJNGAARDEN, A. VAN. The mammal fauna of two Betuwe landscapes. Mammalia, Paris, 21 (3): 267–300. pls. 9–10. September, 1957.

WILKUS, EDWARD. Vergleichend-anatomische Untersuchungen am Kopfe des Wisents—*Bison bonasus* (L.). Teil I—Cavum oris. Acta Theriologica, Inst. Zool. Polska Akad. Nauk, Warsaw, 1 (7): 183–307, pls. 1–18. July 5, 1957. (In Polish, with German and Russian summaries.)

WOO, JU-KANG. *Dryopithecus* teeth from Keiyuan, Yunnan Province. Vertebrata Palasiatica, 1 (1): 25–32, 1 pl. March, 1957.

WORTHINGTON, L. V., AND WILLIAM E. SCHEVILL. Underwater sounds heard from sperm whales. Nature, London, 180: 291. August 10, 1957.

YOUNG, C. C., AND M. M. CHOW. Some Oligocene mammals from Lingwu, N. Kansu. Acta Pal. Sinica, 4 (4): 447–459, illus. 1956. (New: *Archaeotherium ordosius.*)

ZAPFE, H., AND J. HÜRZELER. Die Fauna der miozänen Spaltenfüllung von Neudorf a.d. March (ČSR.) Primates. Sitz.-Ber. Österr. Akad. Wiss., math.-nat. Kl., 166 (2): 113–123, illus. October, 1956. (New: *Pliopithecus* (*Epipliopithecus*) *vindobonensis.*)

ZAPFE, H. Ein bedeutender *Mastodon*-Fund aus dem Unterpliozän von Niederosterreich. Neues. Jahrb. Geol. & Pal., Abh., 104 (3): 382–406, illus. February, 1957.

ZUKOWSKY, LUDWIG. Eine neue Unterart der Zebramanguste aus dem Damaralande, *Mungos mungos damarensis* subsp. nov. Säugetierk. Mitteil., Stuttgart, 4 (3): 113–114. July 1, 1956.

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AAAS Symposium Volume No. 50, devoted to "The Species Problem," is based chiefly on papers presented at a symposium in Atlanta, in December, 1955, cosponsored by the AAAS Section on Botany, the American Society of Parasitologists and the Society of Systematic Zoology. This 404-page work, edited by Ernst Mayr, contains nine separate papers of which several are of special interest to mammalogists. It makes a solid contribution to an understanding of this complex and important issue. The book is available for $8.75 from AAAS Publications, 1515 Massachusetts Avenue, N.W., Washington 5, D.C.; special cash price to AAAS members, $7.50.

SEROLOGICAL RESEARCH

The Serological Museum of Rutgers University, at New Brunswick, New Jersey, recently celebrated its tenth birthday. Although housed in "the most unpretentious international headquarters for anything," it has contributed significantly to zoological science and contains the world's most extensive collection of blood sera, with representatives of all orders of mammals. Particularly needed, however, for a project on systematic serology of vertebrates, are sera of the elephant shrew and the many relatives of the lemur. Anyone who might help fill these gaps is asked to contact the Director, Dr. Alan A. Boyden.

ATLAS OF SWEDEN

A new ATLAS ÖVER SVERIGE is being published by the Svenska Sällskapet för Antropologi och Geografi. This de luxe production, appearing in installments, will be completed by 1960. A recent fascicle (sections 45–46) contains eight pages of maps and text on animal distribution, with legends and summary in English, by Kai Curry-Lindahl. Mammals considered include the hedgehog, lemming, roe deer, lynx, badger, gray and rough seals, and others. Individual fascicles, priced at Sw. Cr. 20:— plus handling and postage, may be ordered from Generalstabens Litografiska Anstalts Förlag, Stockholm 16, Sweden.

CONTRIBUTORS PLEASE NOTE

Your peripatetic editor has removed to the nation's capital. All manuscripts and correspondence should be addressed to him at the Fish & Wildlife Service, U.S. National Museum, Washington 25, D.C., effective at once.

38th ANNUAL MEETING

It is not too late to make arrangements for attending the 1958 Annual Meeting of the Society at Tucson, Arizona, June 16–18. See full details in the February issue, page 173.